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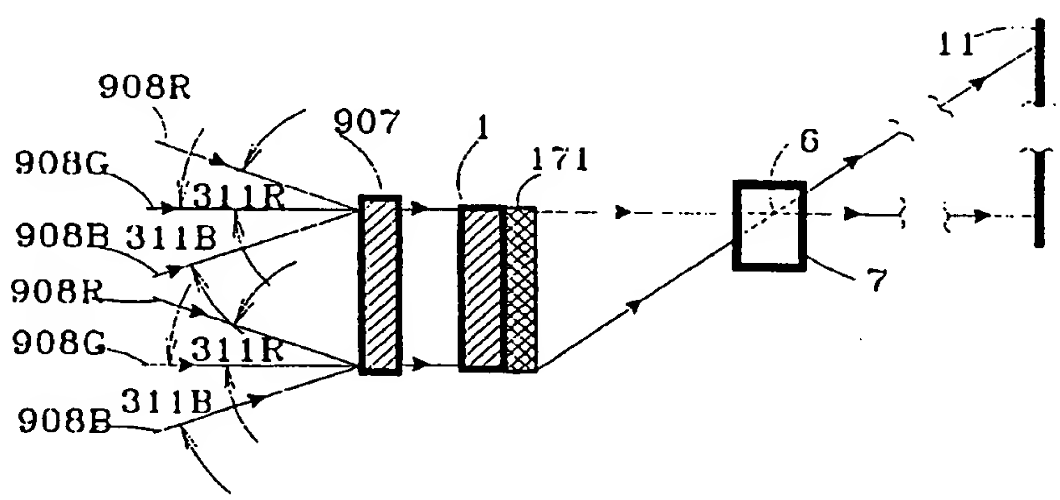

(57) Abstract

A video projection system (10) for color projection which provides a laterally displaced positioning of the projected image or picture on a screen (11). Light of several colors, e.g. generated by arrays of laser diodes (2), passes through a picture-transmitting element (1) and a projection objective (7). The picture-transmitting element (1) is preferably an LCD of the PDLCD-type. Lateral positioning of the picture is achieved either with the aid of microprisms, off-axis microlenses and/or diffractive optical elements (DOE) (71) on the exit side of the picture-transmitting element (1), or by using an off-axis illuminating optic in the form of ellipsoidal mirrors, off-axis Fresnel-lenses (31) or DOE (21) on the entrance side of the picture-transmitting elements.

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TV-projector

According to one primary aspect the invention relates to a projector arrangement of the kind defined in the preamble of the following Claim 1.

According to one aspect the invention thus relates to a projector arrangement in which light of different colors is combined through a picture or image display means, for instance LCD-screens, for off-axis projection on a screen with the aid of one single projection objective without appreciable loss in color filters a particular advantage with such an arrangement is that the image or picture can be made particularly bright and that a good function and good viewing economy is achieved.

Many types of projection systems for projecting video pictures onto LCD-screens are already available commercially, although these systems have not been used to any great extent because of a number of inherent drawbacks.

One drawback with the known projectors is that they offer poor viewing economy. For instance, if the projector is placed in a room in a position which corresponds to half the width of a vertical wall onto which the picture shall be projected, and if the projector is located at a level which corresponds to the height of the viewer's eyes, the centre point of the projected picture, or image, will lie at a corresponding height and width position on the vertical projection surface, so that the projector or viewer will obstruct the picture. It is therefore desirable to obtain a projector construction which will enable the projector picture to be parallel-displaced, for instance so as to allow the projector to be placed adjacent the ceiling or adjacent the floor and/or on a side wall of the projector room.

The illumination systems have a common focal region which in orthogonal projection towards respective picture transmitting elements lies essentially in the centre point of respective elements, resulting in the aforesaid poor viewing ergonomy.

Present day projectors which include one single projection objective can be divided essentially into two main categories. In the first category several different picture-transmitting elements are each transilluminated with light of a single color, with different colors for each of the picture-transmitting elements. The light from the various picture-transmitting elements is then combined or brought together via a dichroic light-combining device comprising dichroic mirrors, for instance in the form of a dichroic prism.

Projectors belonging to the second category have only one picture-transmitting element, which is illuminated with a broader spectrum. The projector includes different color filters in adjacent picture elements, therewith enabling color pictures or images to be projected. A consequent drawback of this second category is that a large amount of light is lost through filtration in the picture element. This also results in heating of the picture-transmitting elements, which may become quite considerable since the light flux transmitted is often high. We shall later illustrate embodiments of projectors which belong to this second category and which do not have the drawback of large light losses in color filters. We shall restrict observations in the following essentially to projectors which belong to this second category - even though it is said below that such considerations are also applicable to projectors which belong to the first category.

Displays which are used in "virtual reality" can be considered as special case projectors belonging to the second category, where one projector is conveniently used for each eye so as to obtain a stereo effect. In this case, the projector objective is corresponded by the lens of the human eye and an

ocular or eyepiece, whereas the projector screen is corresponded by the retina of the eye.

With regard to the ergomony of the viewer, it is necessary to be able to place the projector on one side of the projected picture and above or beneath said picture in the case of front projection. Correspondingly, in "virtual reality" applications an asymmetric projection is required, since the field observed by the eye is asymmetrical - it is possible to observe a larger field towards the temple than towards the root of the nose, and it is possible to observe a wider field downwards than upwards. Thus, there is required in the first case an objective which permits reproduction with large asymmetric fields, and in the second case an ocular which permits large or wide asymmetric fields. Normally it is considered difficult to produce oculars, or eye pieces, with a field greater than about 60° - which is not sufficient when wishing to achieve realistic free vision in "virtual reality".

The object of the present invention is to provide a projection system which will afford improved viewing ergonomy, while another object of the invention according to one aspect thereof is to provide a projector construction which will afford a higher light yield and which is lighter in weight and has a smaller volume, wherein another object of the invention according to another aspect thereof is to provide a projection optic which will enable a picture to be projected from a projector with improved viewing ergonomy in a beneficial manner.

The object of one aspect of the invention is achieved with projection systems in accordance with the accompanying Claim 1.

The further objects of the other aspects of the invention are achieved with the embodiments of the projection system according to the accompanying dependent claims.

Advantageous embodiments of the projection system will be apparent from the accompanying dependent claims.

According to one aspect, the invention is based on a projection system which includes a plurality of picture-transmitting elements, for instance LCD-screens, which are illuminated by several, for instance three, light sources of different colors, which may optionally have been obtained by color separation of light from one single light source, a common projection optic in the beam path downstream of the exit of respective picture-transmitting elements, and a focusing, illumination optic, wherein the projection optic is located in or adjacent the common focal region. Against this background, one aspect of the inventive projection system is mainly characterized in that the common focal region of the illuminating devices is located so that its optical orthogonal projection towards the plane in which the picture-transmitting element lies is essentially displaced or off-set from the centre of the picture-transmitting element, whereby the projected picture or image is parallel-displaced and the desired ergonomical advantage is achieved.

According to a first embodiment in accordance with one aspect of the invention, light from the various light sources is directed onto the picture-transmitting element at different angles of incidence. The light first falls on a positive microlensmatrix or array having a positive lens for each group of different colors that together form a picture point and which focuses the different colors towards separate, negative off-axislenses, which cause the light to pass the picture-transmitting element either orthogonally - in which case it is necessary to provide either off-axis microlenses, microprisms and/or DOE on the exit of the picture-transmitting element, so as to focus the light in accordance with the inventive principle - or focused in accordance with the inventive principle.

According to a second embodiment in accordance with one aspect of the invention, light from the various light sources is directed towards the picture-transmitting element at different angles of incidence. The light first falls on a positive microlensmatrix or array which has a positive lens for each group of different colors that together form a picture point and which focuses the different colors in through respective pixel openings with focus essentially within the pixel openings. A matrix of positive microlenses having an off-axis positive microlens on the exit of each pixel opening which focuses light towards a focal region in the projection objective in accordance with the inventive principle is provided on the exit of the pixel openings. Naturally, light-directing microprisms may also be provided on the entrances to the pixel openings and therewith reduce the demands on the positive microlenses on the exits.

The aforedescribed techniques of using microlensmatrises can also be applied in the case of projectors according to the first category, where a positive microlens is provided on the entry side of each pixel instead.

In accordance with a third and a fourth embodiment according to the second category, the technique including the use of microlens matrises in the first and the second embodiments respectively is combined with focusing the light with the aid of an off-axis field lens on the exit side of the picture-transmitting element, in accordance with one aspect of the inventive principle.

The aforedescribed microlens matrises may conveniently be constructed as planar microlens matrises (PML) manufactured in accordance with a method devised by Dr Masahiro Oikawa, Nippon Sheat Glass, Japan. Becasue these microlenses are planar, embossment is facilitated in, for instance, PMMA of microlenses, microprisms or phase-DOEs thereon.

One method of achieving collimated illumination in the case of systems according to the second category is to use a waveguide plate where collimated flat light beams from all mono-chromatic light sources are led into the waveguide plate at such angles that the light will be totally reflected on the disc defining surfaces. The waveguide disc, however, is provided with phase-DOE with a light-deflecting ability which increases successively along the beam path, so that a uniformly collimated light distribution is obtained from the plate in each of the colors. The direction of each of the colors is determined by wavelength, DOE and the entry angles into the waveguide plate. These entry angles may have a two-dimensional spread, whereby the collimated light exiting from the waveguide plate will also obtain two-dimensional distribution in the different colors. It will be apparent that the described wavelength disc can be used generally as a collimator.

There is obtained with the aid of a waveguide plate a highly compact and lightweight projector according to the second category something which could be referred to as a "Flat Panel Projector" (FPP).

We say in the following that illuminating light which has either an afocal or convergent beam path on the entry side of the picture-transmitting element is collimated and that a device from which collimated light emanates is a collimator.

Another way of illuminating the picture-transmitting element with collimated light is to use off-axis paraboloidal mirrors orellipsoidal mirrors. The advantage with mirrors is that they do not introduce color errors.

It is possible to use projectors that belong to the second category with the aforedescribed technique with waveguide plates with one disc for each color per se, and then to com-

bine or superimpose the collimated light of different colors and directions with the aid of dichroic mirrors. The same applies, of course, to other types of illuminating optics - reflecting or transmitting.

Another possibility is to use waveguide plates in projectors that belong to the second category, using the same waveguide plate for up to two colors and then combining or superimposing (blending) the colors with the aid of dichroic mirrors.

An inherent problem of projectors of the type concerned is that conventional LCD-screens absorb a large part of the light transmission energy in those points that shall be dark, and for this reason it is proposed in accordance with one aspect of the invention that LCD-screens of the PD-type (Polymer Dispersed) are used. Such PD-LCDs are described, for instance, in the article "Field Controlled Light Scattering From Nematic Microdroplets" by the authors J.W. Doane, N.A. Vaz, B.-G. Wu and S. Zumer, Applied Physics Letters 48, 269 (1986). One advantage with PD-LCD-screens is that they have no elevated light absorption upon reproduction of black color but that the light is scattered, thereby enabling a very high contrast to be obtained when an illumination field mixer is placed at the common focal point of the radiation bundles. DP-LCDs of the Active-Matrix-type (AMPDLCDs) are advantageously used.

The LCD-screens shall be transilluminated with light of a plurality of monochromic colors, and according to one aspect of the invention it is proposed for this reason that the LCD-screens are transilluminated with light deriving from essentially monochromic light sources, wherein the light source according to one preferred embodiment may be a laser or diode-laser light source. According to one particularly preferred embodiment of one aspect of the invention the LCD-screen transilluminating light source is comprised of a laser diode matrix or array whose laser light is combined with the aid of

holograhpic optical elements and optionally in combination with lenses, to form a laser light beam. For a closer description of a light source of this nature, reference is made to the article "Beam shaping for high power laser diode array by holographic optical elements" by H.P. Herzig, R. Dändliker and J.M. Teijido, published in the "Second International Conference on Holographic Systems, Components and Applications" in Bath, England, 11-13 September 1989. The article is found in IEE Conference Publication No. 311, 1989, pages 133-137, in which there is described a method of combining or superimposing light from a laser diode array with the aid of two holographic optical elements and possibly an intermediate lens element of 99.3% efficiency, so that it would appear that the light arrives from one single bright laser diode. It is assumed in the aforesaid article that there is used a diode array with precisely the same light wavelength in the individual laser diodes. However, in order for the system to function it is necessary to phase-lock all laser diodes to one another. This is difficult to achieve in practice, however. One alternative is to permit the wavelengths to spread in the individual laser diodes within a range of about 10 nm. This results in an almost periodic function for the combined light intensity. The pulse interval, however, will be very short due to the relatively large band width.

The distribution of light in the resultant laser beam can be given a value which is adapted to obtain uniform illumination of the LCD-screen. The fact that this can be achieved with a difractive optic is shown in the article "Intensity distribution transformation for general beam-shaping" by F.S. Roux and E. van Rooyen, SPIE, Vol. 1052, Holographic Optics Optically and Computer Generated (1989), pages 212-7 (ref. D), among others. The conclusion is drawn in this article that a radially symmetrical intensity in distribution can be transformed to an arbitrary distribution, i.e. it is possible to adapt the light distribution so that it becomes uniform on the LCD-screen. In this regard, there are required two holographic

optical elements and optionally an intermediate lens. In order to obtain the highest possible light transmission, it is convenient to use computer generated phase-holograms produced by electron beam lithography (EBL). This technique is described in the article "Multilevel phase holograms manufactured by electron-beam lithography" by M. Ekberg, M. Larsson and S. Hård, Optics Letters, Vol. 15, (1990), pages 568-9, among other literature. One inexpensive method of manufacturing phase holograms is to produce an embossment tool using, for instance, EBL, and then emboss the phase hologram in a PMMA-layer on a glass substrate.

It is possible to effect the necessary color correction for the relatively narrow bandwidth in the aforedescribed devices. An example of this is described, for instance, in the article "Focusing of Diode Lasers for HIgh Beam Quality in High Power Applications", by the authors Peter Albers, Hans H. Heimbeck, Eckhard Langenbach, presented at the "International Symposium on Optical Systems Design", Berlin 14-18 September 1992, sponsored by EOS and SPIE.

In another preferred embodiment, the light source is a lamp, preferably an arc lamp or a so-called "electrode-less lamp" having a reflector which may be ellipsoidal, spherical or paraboloidal in shape. When the reflector is ellipsoidal, the light arc will lie in the focal point lying in the ellipsoid. When the reflector is spherical, the lamp arc is placed in the centre of the sphere. When the lamp is paraboloidal, the arc is placed in the focal point of the paraboloid. It is possible to use three different lamps, red, green and blue light respectively, or white light can be divided-up with the aid of a dichroic color separating system (DFS), for instance a dichroic prism. When the lamp is mounted so that the axis coincides with the symmetry axis of the reflector, there is obtained a ring-shaped light distribution. A diffusor can be placed in a focal range of the beam path, so as to obtain coherent and uniform light distribution. In one embodiment,

this diffusor may be a microlens variant of a honeycomb condensor (in German Warben condensor). In this way, light distribution can be influenced so as to obtain uniform light distribution over a rectangular area. Another way of achieving uniform light distribution over the LCD-screen is to place in the vicinity of one of the focal regions of the beam path a diffusor which is comprised, for instance, of cross-laid prisms having a randomised prism angle. This enables uniform light distribution to be obtained within an ellipsoidal area. A third method is to use beam-shaping with holographic optical elements according to Ref. D. When starting from a white light source, it is simplest to apply beam-shaping after color separation.

When combining the beam-shaping methods, i.e. the method described in the article "Beam shaping for high power laser diode array ..." and the method described in ref. D, the second DOE in the first reference can be dispensed with.

A third conceivable light source are light emitting diodes which will have the narrowest band possible. These can be combined or superimposed in a known manner, e.g. with the aid of a fiberoptic switch so that light in one and the same color will emanate from a relatively small area. It is possible to use with these light sources the aforedescribed diffractive optical devices to enable the use of the aforedescribed diffractiv optical devices with DOE and waveguide plates.

It is not only the number of pixels that are important to the optical resolution in the picture, but also the arrangement of the pixel elements in relation to one another. It is known already from the art of color printing that a diagonal arrangement of picture points will provide much better picture reproduction than when the picture points are arranged vertically/horisontally. In the case of three-color projection using projectors of the second category, it is best to allow the three color-pixels in a picture point to form a T-shape.

In this way an eqvally long distance is obtained to the nearest pixels for the same color. This distance is also favourably large. This can be achieved by giving the micro-lenses in the positive microlens array or matrix on the entrance to the picture-transmitting element, either a T-shape, a hexagonal shape or a rectangular shape. In this latter case, the rectangular microlenses are disposed in the same way as bricks in a brick wall. The three-color pixels can also be disposed in an L-shape, in which case the positive microlenses in the microlens array on the entrance will also obtain a corresponding L-shape. An hexagonal shape is the most favourable shape in regard of the positive microlenses. Hexagonal shapes can also be obtained with PML-technology.

The most favourable shape for these positive microlenses is obtained with a four-color projector, in which case the four-color pixels are disposed in a square or a rectangle, with the squares or rectangles arranged diagonally, as bricks in a brick wall. The positive microlenses in the microlens array at the entrance to the picture-transmitting element may also have a square or rectangular shape, these shapes conforming well to PML of hexagonal shape. It is also possible to use PMLs in the second embodiment of the projector according to the second category.

One of the fundamental principles for realizing the aims of one aspect of the invention resides in the use of time multi-plexing, optionally in combination with space multiplexing, by dedicating pixels to different colors in one and the same picture-transmission element - either by using color separa-tion techniques or by causing light to be blocked in cells which do not have the color to which the cell is dedicated.

By time multiplexing is meant that the video information is divided in time so as to transmit to the picture-transmission element (PTE) a picture or image as a plurality of partial pictures or images that are separated in time, where each of

these partial pictures or images reproduces picture information for a number of colors.

In accordance with a first embodiment according to second category, the single picture-transmission element (PTE) is illuminated by different time-multiplex light sources of different colors. The light sources are controlled in correlation with the picture information sent to the picture-transmission element (PTE), so that information in a first color is generated via the PTE when the PTE is illuminated with the color in question. In this case, only a minimum number of pixels are able to generate pictures or images with very good color reproduction.

In accordance with a second embodiment according to the second category both time multiplexing and space multiplexing are used in the single PTE. Time multiplexing is carried out in the manner described above, whereas space multiplexing is effected by color separation with the aid of microlens arrays in accordance with the two principles described above.

One aspect of the invention is the application of "virtual reality", in which the first embodiment may be preferable since it does not require such a large light flux. In order to obtain good and natural viewing ergonomy, it is necessary for the field angle on the side of the observer to be at least 60°, and preferably larger. In order to facilitate the design of the ocular or eyepiece, it is therefore suitable to illuminate the PTEs with convergent light. The naturally observed field is not rotationally symmetrical. The field has a larger angle downwards than upwards. In order to further facilitate the design of an ergonomically configured ocular it may therefore be suitable to configure the lighting so that at the bottom edge of the PTE the light has a larger outwardly directed angle of incidence than the downwwardly directed angle at the upper edge. In order to eliminate color aberrations emanating from the illuminating optic it is preferred to use an off-axis ellipsoidal mirror with the light sources or picture or image thereof in one focal point of the mirror

while placing the other focal point of the mirror without an ocular or eye piece as close as possible to position of the pupil of the eye - with regard to the possible angles of incidence on the PTE. In order to obtain the best possible light distribution, a diffusor can be placed in the beam path inwardly of the ellipsoidal mirror or its correspondence in the vicinity of a region or area common to all light sources.

Different aspects of the invention will now be described with reference to examples thereof and also with reference to the accompanying drawings. The first two drawings give general descriptions of the fundamental embodiments.

Figure 1 illustrates schematically the principle structural design of projectors belonging to the second category in accordance with the first and the third embodiment, wherein light of different colors falls at different angles onto an array of afocal microlens systems on the entrance side.

Figure 2 illustrates schematically the principle structural design of projectors belonging to the second category in accordance with the second and the fourth embodiment, wherein light of different colors falls at different angles onto an array of positive microlenses on the entrance side with a further array of positive microlenses on the exit side.

Figure 3 illustrates schematically a projector system which is displaced in the height and lateral directions in relation to the centre of a vertical display screen.

Figure 4 illustrates schematically illumination of a picture-transmitting unit provided with an array of laser diodes.

Figure 5 illustrates schematically how the principle illustrated in Figure 20 functions when using microlenses or microlens surfaces.

Figures 6 and 7 are two orthogonal projections illustrating schematically a projector belonging to the second category, in which only one single picture-transmitting element is used.

Figures 8 and 9 illustrate schematically in two orthogonal projections how color separation and transmission through the

pixel openings is achieved in the projector illustrated in Figures 6 and 7.

Figure 10 shows the form of a positive microlens in the systems shown in Figures 6-9.

Figure 11 illustrates adaptation of the light beam through the pixel opening to the shape of said opening.

Figure 12 illustrates the coverage of a surface with micro-lenses of the type shown in Figure 10.

Figures 13 and 14 illustrate schematically the construction of a color channel in which a DOE or system of microlenses/-microprisms is included on the exit side of the picture-transmitting element.

Figure 15 illustrates schematically the principle construction illustrated in Figures 13 and 14, in which a microlens or a microprism is provided after each pixel opening.

Figure 16 illustrates schematically an example of the con-struction of three color channels extending from the light source to the screen.

Figure 17 illustrates schematically the construction of a diffusor with cross-laid prisms of random inclination or slope.

Figure 18 illustrates schematically the conversion of arbit-rary light distribution to a uniform and essentially rec-tangular distribution, with the aid of a honeycomb condensor placed in a focal region.

Figures 19 and 20 illustrate schematically the construction of the microlens arrays included in the honeycomb condensor.

Figure 21 illustrates a three-color projector belonging to the second category, in which a waveguide plate is used for illumination purposes.

Figure 22 illustrates a method of arranging the pixel elements in the picture-transmitting element in the projector shown in Figure 21.

Figure 23 illustrates a method of arranging the positive microlenses in the projector shown in Figure 41 with the pixel arrangement shown in Figure 22.

Figure 24 is a detail study of the projector shown in Figure 21.

Figure 25 illustrates very schematically a detail study of an LCD-projector, using color separation technique.

Figure 26 illustrates an alternative, preferred method of arranging positive microlenses in the projector shown in Figure 21 with the pixel arrangement shown in Figure 22.

Figure 27 illustrates a preferred method of arranging the pixel elements in a four-color projector belonging to the second category.

Figure 28 illustrates a method of arranging the positive microlenses on the entrance to the picture-transmitting element in a four-color projector belonging to the second category.

Figure 29 illustrates a preferred method of arranging the positive microlenses on the entrance to the picture-transmitting element in a four-color projector belonging to the second category.

Figures 30 and 31 illustrates two projections of a four-color projector belonging to the second category, with a waveguide plate as illumination optic and with a positive microlens array on both the entrance and the exit of the picture-transmitting element.

Figure 32 shows a detail study of the projector illustrated in Figures 30 and 31

Figures 33-35 show three projections of the first embodiment according to the second category, with collimated light in three colors from the three waveguide plates.

Figure 36 illustrates schematically a three-color video projector of the second category, in which only time multiplexing is used.

Figure 37 illustrates schematically a six-color video projector in which both time multiplexing and space multiplexing are used and in which the illumination light is combined with the aid of three ellipsoidal dichroic mirrors.

Figure 38 illustrates schematically the one projector in a three-color "virtual reality" application.

Figures 39-41 illustrate the princple of oblique projection.

In the following description of Figures 1-38 the suffixes R, G and B are used to identify light of different colors and devices that are dedicated to this light. The reference numeral 2 identifies a general light source. When using a broadband light source, such as an arc lamp, light sources 2R, 2G and 2B can conceivably be obtained from this one single light source by color separation with the aid of color separating filters. The reference numeral 1 identifies a picture-transmitting element. The reference numeral 7 identifies the projection objective which reproduces on the projection screen 11 the picture or image generated by the picture-transmitting element 1. The reference numeral 6 identifies the region onto which light is focused by the illuminating object in all colors.

Figure 1 illustrates schematically the structural design of projectors of the second category according to the first and the second embodiment, where light of different colors falls at different angles onto an array or matrix 907 of afocal microlens systems. The reference numeral 171 identifies an optic which is comprised, for instance, of microprisms or off-axis field lenses and which collects the light adjacent the focal region 6. Reference 311R denotes the angle between the color R and the color G. The reference 311B denotes the angle between the color G and the color B.

Figure 2 illustrates schematically the structural design of projectors belonging to the second category in accordance with the second and the third embodiment, wherein light of different colors falls at different angles onto an array 322 of positive microlenses. The reference numeral 324 identifies an array of positive microlenses. The reference 171 identifies an optic comprised, for instance, of microprisms or off-axis field lenses, which collects the light adjacent the focal region 6. The reference 311R denotes the angle between the

color R and the color G. The reference 311B denotes the angle between the color G and the color B.

Figure 3 illustrates schematically a projector arrangement 10 which is displaced in a height direction and laterally in relation to the center of a vertical picture screen 11.

Figure 4 illustrates schematically a laser diode field (LDA) 200 which is followed by a first diffractive optical element (DOE) 201, and a second DOE 203 which is spaced from the first DOE, and optionally an intermediate lens 202, to generate a beam of laser light 205 with a light distribution which as yet is not adapted to provide uniform illumination of the picture-transmitting unit 979, which comprises focusing and picture-transmitting elements among other things. With the aid of a further two DOEs 208, 209 and optionally an intermediate lens 204 there is achieved in the light beam or light bundle 207 a light distribution such as to illuminate the picture-transmitting unit 979 located downstream of the negative lens 206 with the same quantity of light through each pixel. It is necessary in this regard to take into account the fact that the angles of incidence of the light will vary in relation to the various pixels in the picture-transmitting element. The virtual picture or image from which the light that illuminates the picture-transmitting unit appears to emanate can be used to form the generally punctiform light source 2 for trans-illuminating the associated picture-transmitting element 979. As earlier shown, it may be suitable to provide a collimating or focusing optic in front of the picture-transmitting element. The fundamental features of the light source illustrated in Figure 4 are described in the article "Beam shaping ..." and in ref. D mentioned in the introduction. The DOE 203 can be omitted.

Figure 5 illustrates the principle of how the transmission of light through the pixel openings is increased with the aid of the microlens system. In front of each pixel opening 26 there

is placed a positive lens 24 and a negative lens 25 whose axes essentially coincide with the main direction of the light incident on the picture-transmitting element. The lenses 24 and 25 together form an afocal system which concentrates the light through the pixel openings.

Figures 6 and 7 are schematic orthogonal projection views of a projector belonging to the second category, in which only one single picture-transmitting element is used. The reference numeral 398 identifies a collimating optic, which may be a Fresnel-lens for instance. The reference numeral 322 identifies an array of positive microlenses, while reference numeral 323 identifies an array of negative microlenses. The reference numeral 71 identifies an array of microlenses, microprisms and/or DOEs.

Figures 8 and 9 are two orthogonal projections illustrating a detail study of the system shown in Figures 6 and 7. In this case, light of color G falls on the array 322 of positive microlenses 94. Light of color R on the array 322 at a projection angle 311, while light of color B on the array 322 at an angle 312 to the former orthogonal projection. As illustrated in Figure 10, the extension of the lens 94 is such as to cover an area which is equal to the three pixels required to reproduce a picture pixel in three colors. It can easily be shown that a surface area can be covered completely with lenses of this form. Light in the aforesaid three colors R, G, B will now be separated and fall on negative microlens elements 314R, 314G, 314B, which in turn cause the light to be collimated and to pass through respective pixel openings 315R, 315G, 315B in the LCD 1. The array of microlenses, microprisms and/or DOE 71 then cause the light to be focused onto the point 6, as illustrated in Figures 6 and 7.

Figure 11 shows how the shape of the light beam 91 through the pixel opening 315 has been adapted to the shape of the pixel opening defined by the frame 92 and the transistor element 93.

Because of the smallness of the microlenses, significant diffraction is obtained and it may therefore be necessary, among other things, to prevent stray light of a given color for a given pixel opening entering adjacent pixel openings intended for other colors, by using with each pixel opening some form of color filter which will allow only light of that particular color for which the pixel opening is intended to pass through.

Figure 12 shows how a surface can be completely covered with lenses of the form illustrated in Figure 10. Reference numeral 944 identifies the generating form, which is precisely the same for the positive lens as for a group of the three differently colored pixels that together form a picture pixel. The pixels for the three different colors are referenced PR, PG, PB. It will be seen that the distance between adjacent pixels in the same color is large on average. They meet solely with corner contact along one diagonal. It is suitable to arrange the transistors (93) of the pixel elements along this diagonal, so as to improve separation between adjacent pixels in the same color.

Figures 13 and 14 illustrate schematically how light transmitted through a picture-transmitting element 1 can be focused onto the focal region 6 in accordance with one aspect of the inventive principle, with the aid of DOE microprisms or off-axis microlenses 71. Figure 14 is a view of the arrangement shown in Figure 13 taken on the line V-V in said Figure.

Figure 15 illustrates schematically the case when the element 71 in Figures 31 and 32 is comprised of microprisms or off-axis microlenses 72 behind each pixel opening 315. The elements 72 may, of course, also be "Fresnelized".

Figure 16 illustrates schematically an example of the construction of one of the three color channels all the way from the light source 777 to the screen 11. The light source 777

may either be monochromatic or quasi-monochromatic and is generated, for instance, from laser diodes or arc lamps respectively, as described in the aforegoing. The component 204, 208, 209 have the same function, to produce desired light distribution as described in Figure 4. The negative lens or the DOE spreads light over the whole of the LCD-screen 1. The component 73 may be a DOE or a Fresnel-lens and functions to collimate the light so that it will fall orthogonally on a matrix or array of microlenses 22, 23, which collects the light in through the pixel openings.

Figure 17 illustrates schematically a diffuser with cross-laid microprisms. Microprisms provided on the plates 41 and 42 are disposed so that the prisms 42 will be orthogonal to the prisms 41. They are placed close together in a focal area of the illuminating light beam in front of the picture-transmitting elements. The slope or inclination of the prisms has a random distribution, so as to equalize the angular distribution. The light distribution can be adapted to the HDTV-format, by giving, for instance, the prisms 41 a distribution over an angular range which is different to the angular range of the prisms 42. The design of the diffusor can be facilitated, by placing an essentially collimating optic in the front in the beam path.

Figure 18 illustrates a microlens-variant of a honeycomb condensor placed in the focal region of the beam path. The reference numeral 663 identifies an array of rectangular microlenses. The reference numeral 664 identifies an array of hexagonal microlenses. The microlenses are configured in a known manner so that the collimating optical element 668, which may be a Fresnel-lens, is uniformly illuminated. The design of the honeycomb condensor can be facilitated, by placing a collimating lens 798 in front of the condensor. The diameter of the honeycomb condensor should be as small as possible, so as to obtain a good contrast when projecting. A diameter of 1-5 mm is believed to be appropriate, in view of

the fact that the ratio between said diameter and the distance from the collimating optic 668 should be at most in the order of 0.01. The same also applies, of course, to the diffusor shown in Figure 17.

Figure 19 illustrates the pattern of the microlenses 665 in the microlens array 663 shown in Figure 38. The microlenses 665 have the same proportions as the element 668, which in the HDTV-case is 16:9.

Figure 20 illustrates the pattern or configuration of the microlenses 667 in the microlens array 664. Each microlens 665 essentially reproduces ,or images the light source in a single microlens 667, which in turn reproduces or images the microlens 665 on the element 668. The honeycomb condensor is constructed so that the area illuminated on the microlens array 664 will be in the order of 1 to 2 mm, depending on the size of the light source. The illuminated area of the microlens array 663 is typically ten times greater than the area illuminated on the microlens array 664.

Figure 21 illustrates a three-color projector FPP belonging to the second category. The first embodiment in which illumination is effected with a waveguide plate 601. Monochromatic light from respective light sources 2R, 2G and 2B is combined via the dichroic prism 555 to the band-formed cylinder lens 603, which may be a Fresnel-lens and which collimates the light within the waveguide plate 601. The angular distribution out from the waveguide plate will either be two-dimensional or one-dimensional, depending on the relative angular distribution of light of the different wavelenghts exiting from the dichroic prism 555. The light exiting from the waveguide plate will then pass the color-separating positive microlens array or matrix 322 and then the collimating negative microlens array or matrix 323. The reference numeral 71 identifies some form of field lens, which may be comprised, for instance,

of microprisms on the exit of the pixel elements, optionally combined with an off-axis field lens.

Figure 22 illustrates a method of arranging the pixel elements PR, PG and PB in the picture-transmitting element in the projector shown in Figure 21. The pixel elements have associated pixel openings 315R, 315G and 315B.

Figure 23 illustrates a method of arranging the positive microlenses 94 in the projector shown in Figure 21 having the pixel arrangement shown in Figure 22. A microlens 94 covers precisely the surface area that is covered by the rows of pixel elements PR, PG and PB together.

Figure 24 is a highly schematic illustration of an LCD-projector using a color separation technique, i.e. a technique in which the different colors R, G and B are separated prior to entering dedicated light valves or light switches 1R, 1G and 1B. Light arrives in the mutually different directions 311 and 312 to a microlens array 322 having positive microlenses 94. Light of the three different colors will each fall on its respective negative microlens 314R, 314G and 314B in a second microlens array 323 and then pass to its respective light valve 1R, 1G and 1B in an LCD-array 1, whereafter they reach the light-directing, color-corrected combinations 7R, 7G and 7B of diffractive array or matrix elements and microprisms in the arrays or matrises 21 and 22.

Figure 25 is a highly schematic illustration of an LCD-projector which uses a color separation technique, i.e. a technique in which the different colors R, G and B are separated within dedicated light valves 1R, 1G and 1B. Light arrives, in the mutually different directions 311 and 312, at a microlens array 322 having positive microlenses 94. Light in the three different colors falls* on its respective light valve 1R, 1G and 1B in an LCD-array 1, whereafter they reach the light-directing, color-corrected combinations 7R, 7G and 7B

of diffractive matris or array elements and microprisms in the arrays or matrises 21 and 22.

Figure 26 illustrates an alternative, preferred method of arranging positive microlenses 994 in the projector shown in Figure 21 with the pixel arrangement shown in Figure 22. In this case, it is necessary for the light that falls on the positive microlens array to have a two-dimensional distribution adapted to the two-dimensional T-configured arrangement of the pixel elements PR, PG and PB. Instead of T-configured microlenses, it is possible to use to advantage hexagonal microlenses with one microlens for each group of three-color pixels and covering completely the surface area of the picture-transmitting element 1.

Figure 27 illustrates a preferred method of arranging the pixel elements PA, PB, PC and PD in a four-color projector belonging to the second category.

Figure 28 illustrates a method of arranging the positive 995 microlenses on the entrance to the picture-transmitting element in a four-color projector belonging to the second category. In this case, each microlens covers precisely the surface area corresponded by the pixel elements PA, PB, PC and PD.

Figure 29 illustrates a preferred method of arranging the positive microlenses 996 in honeycomb form on the entrance to the picture-transmitting element in a four-color projector belonging to the second category. One advantage afforded by this form is that it provides for cheaper manufacture in the form of planar microlenses (PML).

Figures 30 and 31 are two projection views of a four-color FPP-projector belonging to the second category, the second embodiment, comprising a waveguide plate as an illuminating optic and having a positive microlens array or matrix 322F on

the entrance of the picture-transmitting element and a 324 on the exit of the picture-transmitting element. Figure 31 is a projection view of the projector shown in Figure 30, taken on the line CLI-CLI. Divergent flat light beams from the four monochromatic light sources 2A, 2B, 2C and 2D, which have different wavelengths, said flat light beams having main directions with two-dimensional distribution, enter the elongated cylinder-lens 603, which functions to collimate the light prior to its entry into the waveguide plate 601. The uniformly distributed light arriving from the waveguide plate 601 and collimated in all colors then arrives at the array 322F having positive microlenses, which may advantageously be PLMs, as shown in Figure 28. There is located on the exit of the pixel openings an array of positive microlenses, which may also advantageously be PLMs. Also provided is a field lens 71 in the form of microprisms, optionally in combination with an off-axis field lens.

Figure 32 is a detail study of the projector shown in Figures 30. Reference numeral 601 identifies the waveguide plate at which light arrives at such angles as to be totally reflected multiply, but which on the surface 601D has a phase-relief grating whose relief depth increases successively along the beam path. The glass surface on the entrance to the picture-transmitting element, which may advantageously be of the dispersive kind, is provided with positive PLMs 94F which separate the light into all four colors and focus the light in through respective pixel openings 315A and 315B and also through the pixel openings 315C and 315D hidden behind said pixel openings 315A and 315B. The glass surface on the exit of the picture-transmitting element is provided with a positive PMLs 317A and 317B and also 317C and 317D hidden behind 317A and 317B for each pixel opening and also with microprisms 318A and 318D and also 318C and 318D hidden behind 318A and 318D - optionally in combination with an afocal field lens for focusing onto the focal region 6 in the projection objective. The microprisms may advantageously be produced by embossing

a PMMA coating on the surface provided with PMLs. The phase grating on the surface 601D of the waveguide plate can also be obtained by embossing a PMMA-layer.

Figures 33-35 are three projections of the second category, the first embodiment, with collimated light in three colors from three waveguide plates 601R, 601G and 601B which collimated with different angles of incidence are combined with the dichroic prisms in towards the array 322 of color-separating positive microlenses, preferably in the form shown in Figure 26. The reference numeral 322 identifies an array of negative microlenses which collimate the light into the pixel openings in the picture-transmitting element 1, which is provided on its exit with microprisms which, optionally together with an off-axis field lens, focus the light in through the objective 7 to the focal region 6, where an illumination-field mixer is located.

Figure 36 illustrates schematically the construction of a purely three-fold time-multiplexed three-color projector having only one PTE1. The video signal arrives at the multiplexor unit 22 via V, where the signal is divided timewise into one signal for each of the three colors sent to the PTE1 via L. At the same time as video information in the PTE1 switches from one color to another, a corresponding light source 2A, 2B, 2C is activated via D1, D2 and D3 respectively. The light from the light sources 2A, 2B, 2C is directed in towards a diffusor unit 8 which, for instance, may be configured as shown in reference A with cross-laid microprisms of such statistic distribution of the prism angles as to obtain uniform illumination of the PTE1 subsequent to the light having been reflected on the ellipsoidal mirror 4, the one focal point 9 of which lies in the diffusor unit 8 and the other focal point 6 of which lies in the objective 7. Alternatively, the diffusor units may have the form of microlens-variants of a honeycomb condensor shown in ref. A. The picture on the screen 11 can be displaced both vertically and

laterally, by appropriate positioning of the focal point 6. A lens optic may be used instead of an ellipsoidal mirror. The illuminating optic 4 may also be a collimating optic, for instance by using a parabolic mirror or a lens optic. In this regard, some form of refractive optic should be provided on the exit of the PTE1, for instance in the form of a microprism array which focuses the main beams within the objective 7 onto the focal region 6, preferably in two dimensions laterally displaced. In order to improve the efficiency of light transmission through the PTE, it may be convenient to use microlens arrays to focus the light in through the pixel openings, in a known manner. We have here produced a three-color projector with the use of solely one PTE. Naturally, the same principle can be applied for any desired number of colors. However, one problem that may arise with a large number of colors is the high speed at which the PTE is then required to operate.

Figure 37 illustrates schematically an inventive six-color projector system which uses six-fold time-multiplexing with three-fold color separation in the PTE1. The light is collimated and combined with the aid of three series-connected ellipsoidal mirrors 4, 4′, 4", the focal point of which coincides with the virtual light source 9 and the other focal point of which is at 6, 6′ and 6" respectively. The ellipsoidal mirrors 4 and 4′ are dichroice so as to reflect solely their respective color of the said three colors, while the remaining colors are transmitted. Color separation is effected with microlens arrays in the PTE 1K in the manner disclosed in either reference A or reference B. The lens 23 is used in a manner similar to that disclosed when describing the system illustrated in Figure 3. The light source 2 includes a total of six different color light sources which are controlled via the connections D1-D6. The illumination optic has been shown only schematically and may be constructed in accordance with the alternatives shown in ref. A - optionally in part also included in unit 1K in the form, for instance, of microprisms

or diffractive optical elements on the exit which focuses the light onto the objective 7. Alternatively, the illumination optic 4 gives essentially collimated light by using paraboloid mirrors instead of ellipsoidal mirrors, whereas, for instance, microprisms or diffractive optical elements on the exit of the PTE 1K directs the light onto the region 6 in the objective 7. The video signal V arrives at the multiplexor unit 22, which divides timewise the video information relating to the six colors into two groups each containing three colors. In conjunction with activating the video signal for the first color in the PTE 1K via L, a first light source is activated via D1. When the video signal for the second color is then active in PTE 1K, a second light source is activated via D2. In the next phase, when the video signal for the third color in the PTE 1K is activated via L, the third light source is activated via D3, and so on until all six colors have been projected, this procedure being defined as a cycle. It may be convenient to carry out about 200 such cycles per second, although a lower frequency of, for instance, 70 cycles per second may be sufficient. By selecting the colors in the six light sources in three groups where the colors lie spectrally close to one another, and color separation can be achieved in groups in the way described in ref. A or ref. B by giving light in these three groups slightly different angles of incidence into the PTE 1K. The use of this three-fold color separation color information relating to three colors to be activated simultaneously in the PTE 1K, therewith reducing the speed at which the PTE 1K need operate by a factor of three, in comparison with the case when no color separation is used. Thus the same speed requirement is placed on the PTE, although with the advantage that only one PTE is required instead of three. The colors can be activated in any desired sequence in a cycle, although it is necessary to first choose all three colors for which the video information is first stored in the PTE 1K. In each of the two groups of color video information active simultaneously in the PTE, it is a generally red, a

generally green and a generally "blue" color so that it can be said that two RGB-signals alternate in time.

It will be understood that the system illustrated in Figure 37 can be used as a three-color projector without time multiplexing, either with three ellipsoidal mirrors or three paraboloidal mirrors.

Figure 38 is a schematic side view of one of two purely time-multiplexed three-color projectors in a virtual reality application. The video signal arrives at the multiplexor unit 22, via V, where the signal is divided timewise into a signal for each of the three colors prior to the PTE 1 via L. At the same time as the video information in the PTE 1 switches from one color to another, corresponding light sources 2A, 2B, 2C are activated via D1, D2 and D3 respectively. The light from the light sources 2A, 2B and 2C is directed in towards a diffusor unit 8, which, for instance, as shown in ref. A, may be provided with cross-laid microprisms of such statistic distribution, with regard to the prism angles, as to obtain uniform illumination of the PTE 1 after the light has been reflected on the ellipsoidal mirror 4, the one focal point 9 of which lies in the diffusor unit 8 and the other focal unit point 6 of which lies behind the eye E. Alternatively, the diffusor units may have the form of microlens-variants of a honeycomb condensor as shown in ref. A. In order to facilitate the construction of the ocular or eye piece 24, the light emanating from the three light sources 2A, 2B, 2C is focused onto the point 6 such that the angle A1 will be larger than the angle A2 out from the PTE 1. The ocular 24 is configured in accordance with the fundamental concept on the use of decentering as discussed with regard to the projection objective in ref. A. Since the eye sees a smaller field upwards than downwards, the angle B1 will preferably be smaller than the angle B2. Suitable angles are $0<A1<20$, $0<A2<30$, $10<B1<40$ and $30<B2<60$ degrees. The size of the exit pupil that coincides with the pupil of the eye E is determined, among other

things, by the spread of the virtual light source 9. The exit pupil will preferably have a diameter of 1 to 2 cm. Analogously, larger angles can be chosen outwardly in a lateral direction than inwardly towards the root of the nose. We have here a compact construction for showing "virtual reality"-pictures or images in three colors. The system can be constructed analogously for six colors for instance. Another decisive advantage is that a large, possibly asymmetric field of vision is made possible because the main beams are convergent in towards the ocular.

Figure 39 is a highly schematic illustration of one aspect of the invention in which the projection objective ($\bar{1}$) projected orthogonally to the plane of the picture-transmitting element (1), will lie outside the optically active surface (1) of the picture-transmitting element so that the main beam which passes from the corner nearest the objective to the objective will form an outwardly rotated angle B1 in relation to a normal (N1) to the picture-transmitting element (1), said angle being of the order of 0-20° for instance.

Figure 40 illustrates schematically how a projector according to Figure 39 is placed in relation to the screen 11. The projection objective 7 will lie essentially on the extension of a diagonal of the corners H1 and H2 of the projected picture.

Figure 41 illustrates schematically a view of the arrangement shown in Figure 40, taken on the line A-A in said Figure wherein the view is orthogonal to the diagonal H1-H2 in the picture (11) and wherein the beam (S1) passing from the projection objective (7) to the nearest corner (H1) of the projective picture (11) forms an angle V2 which lies in the range of 0-20°.

Since a paraboloid is a special case of an ellipsoid, the ellipsoids of all of the aforedescribed arrangements or systems can be replaced with paraboloids and vice versa.

Although it has been assumed when describing the illustrated systems and arrangements that the projected picture is displaced both vertically and horizontally, it will be understood that the arrangements can be constructed so as to obtain a more or less central, conventional projection.

The aforedescribed diffusors can replace totally the earlier (ref. D) described diffractive system for "beam-shaping".

What has been referred to above as the orthogonal projection of an object to a plane (e.g. a picture-transmitting element) relates to something that could be called optical orthogonal projection to the plane and which would be an orthogonal projection if flat mirrors were not found between the object and the plane. In a tunnel diagram it becomes a conventional orthogonal projection. Analogously, it can be said that a plane is optically parallel with another plane.

One method of reducing the requirements placed on the array or matrix 71 on the exit side of the picture-transmitting element 1 in Figures 13-16 and Figures 6-9 is to permit collimated light to fall on the picture-transmitting element 1 in a direction which is directed towards an inner part of the projection screen 11.

<u>Claims</u>

1. A projection system comprising a picture-transmitting element (1, 1K) which includes a plurality of pixel openings (315R, 315G, 315B) provided with light valves or light swit-ches, a projection optic (7) in the beam path between the picture-transmitting element (1, 1K) and the picture screen (11), a number of light sources (2, 2R, 2G, 2B) and an illu-mination optic (71, 171, 398, 4, 4′,4″, 601, 703, 73), wherein the illumination optic functions to focus the light from the light sources (2) in a focal region (6) at the projection optic (7), **characterized in that** the illumination optic is constructed to direct the light towards the focal region (6) which is common to the light sources (2) and which is located so that the optical orthogonal projection thereof towards the picture-transmitting element (1, 1K) is displaced from the center of the picture-transmitting element (1, 1K) to produce a corresponding parallel-displaced, distortion-free projection picture or image on a projection screen (11) which is optically parallel with the picture-transmitting elements.

2. A system according to Claim 1, **characterized in that** diffractive optical elements, microlenses and/or microprisms (72, 318) are arranged on the exit of each pixel opening (315, 26) so as to direct the light towards the common focal region (6).

3. A system according to one of Claims 1-2, **characterized in** that the picture-transmitting element (1, 1K) is illuminated with light in different colors collimated, or with convergent light and with mutually different angles of incidence; in that the picture-transmitting element (1, 1K) is formed by a plurality of essentially identical, closely packed and gene-rally rectangular pixel elements (PR, PG, PB - PA, PB, PC, PD) having pixel openings (315R, 315G, 315B - 1R, 1G, 1B); in that the pixel elements are disposed in mutually equal and simiarly orientated groups of pixel elements for each of the

colors, wherein the pixel elements of each group are intended to be transilluminated by light of a number of colors in each pixel element.

4. A system according to Claim 1-2, **characterized** in that time multiplexing is used by virtue of a multiplexor unit (22) alternatingly activating different light sources (2A-F) at the same time as relevant picture information concerning the activated color is active in an associated picture-transmitting element (1, 1K).

5. A system according to the two Claims 3 and 4.

6. A system according to Claim 5, **characterized** in that light of several spectrally adjacent colors is sent alternately to one and the same pixel element (315R, 315G, 315B - 1R, 1G, 1B).

7. A system according to any one of Claims 1-6, **characterized** in that collimated or convergent light of several colors (908R, 908G, 908B, 91) is arranged to fall at the entrance to the picture-transmitting element (1, 1K) in different relative directions (311, 312 - 311R, 311B) onto an array (907 or 322, 323) of essentially afocal microlens-system having a positive system-part (322; 94) and a negative system-part (323; 314R, 314G, 314B) so that the different colors will essentially be transmitted through their respective local picture elements (315R, 315G, 315B - 1R, 1G, 1B); and in that the positive microlenses have the same form as the groups of pixel elements or a hexagonal or rectangular form with the same surface area as said group.

8. A system according to any one of Claims 1-6, **characterized** in that collimated or convergent light of different colors and having different relative directions (311, 312) with regard to the different colors falls on an array (322, 322F) of positive microlenses (94, 94F), whereby the light is

separated into said different colors and focused prior to entering respective light valves or switches (315 - 315R, 3154G, 315B - 1R, 1G, 1B - 315A, 315B), which after each light valve are followed by positive microlenses and/or DOE (317A, 317B) which together form an array (324); in that the positive microlenses (94, 94F) have the same form as the groups of pixel elements or have an hexagonal or a rectangular form with the same surface area as said group; in that the positive microlenses and/or DOE (317A, 317B) have the same form as the pixel elements or have an hexagonal or a rectangular form with the same surface area as the light valves.

9. A system according to any one of Claims 1-8, **characterized in** that the common focal region (6) of the illumination optic is located so that the optical orthogonal projection thereof to respective picture-transmitting elements (1, 1K) will lie in the proximity of one edge of the picture-transmitting element (1, 1K).

10. A system according to any one of Claims 1-9, **characterized in** that the focal region (6) of the illumination optic common to all light sources is located so that the optical orthogonal projection thereof to respective picture-transmitting elements (1) will lie in the proximity of one corner of the picture-transmitting element (1).

11. A system according to any one of Claims 1-10, **characterized in** that the focal region (6) of the illumination optic common to all light sources is located so that the optical orthogonal projection thereof to respective picture-transmitting elements (1) will lie outside a corner of the picture-transmitting element (1) so that the beam (S1) which passes from the objective (7) to the nearest corner (H1) on the projection screen (11) will define an angle (V2) of between 0 and 20° with a normal to the screen (11).

12. A system according to any one of Claims 1-11, **characterized by** a transluscent-LCD-screen.

13. A system according to Claim 12, **characterized in** that the picture-transmitting element (1, 1K) is of a dispersive type.

14. A diffusor where an irregular light distribution (920) from the light sources (2) is converted to uniform illumination of an essentially regular surface (1, 1K), **characterized in** that the diffusor is a microlens-variant of a honeycomb-condensor (663, 664) which is optionally preceded in the beam path by an essentially collimating objective (798).

15. A diffusor where an irregular light distribution (920) from the light sources (2) is converted to uniform illumination of an essentially regular surface (1, 1K), **characterized in** that the diffusor is essentially obtained by placing cross-laid microprisms (41, 42) having random prism-angles with a determined distribution within a given range in a focal region of the beam path (43); and in that the cross-laid microprisms are optionally preceded in the beam path by an essentially collimating optic.

16. A system according to any one of Claims 1-13 and any one of Claims 12-13, **characterized in** that light from the light sources (2) is focused onto a number of diffusor units (8).

17. A system according to any one of Claims 1-16, **characterized in** that a plurality of differently colored illumination light fluxes on the entrance side of the picture-transmitting element (1, 1K) are combined by a combining device (5).

18. A system according to any one of Claims 1-17, **characterized in** that the illumination optic on the entrance side of the picture-transmitting element (1, 1K) is comprised partially of a plurality of dichroitic ellipsoidal mirrors (4,

4', 4") having a light source or real or virtual image of a light source in a focal point (9) which is common to the ellipsoids, while the other focal point (6, 6', 6") of the ellipsoids is not common to the ellipsoid mirrors.

19. A system according to any one of Claims 1-17, **characterized in** that only one ellipsoidal mirror (4) is used as an illumination optic on the entrance side of the picture transmitting element (1, 1K) with a light source or real or virtual image of a light source in the one focal point (9) of the ellipsoid.

20. A system according to any one of Claims 18-19, **characterized in** that the orthogonal projection of the second focal point (6, 6', 6") to the picture-transmitting element (1) lies excentrically on the picture-transmitting element (1).

21. A system according to any one of Claims 18-19, **characterized in** that the illumination optic (4) is comprised of a plurality of paraboloidal mirrors with the focal point (9) essentially coinciding with a light source or a real or virtual image of a light source, with the symmetry axes not in a common direction.

22. A system according to any one of Claims 18-20, **characterized in** that the orthogonal projection of the second focal point to the picture-transmitting element (1) lies excentrically on the picture-transmitting element (1); in that the maximum field angle (A1) on the exit of the upper side of the picture-transmitting element (1) is in the order of 0-20°; and in that the maximum field angle (A2) on the exit of the underside of the picture-transmitting element (1) is in the order of 0-30°.

23. A system according to Claim 22, **characterized in** that the projection optic is comprised of an ocular provided with a decentered lens element; in that the maximum field angle (B1)

on the exit of the upper side of the ocular (24) is in the order of 10-40°; and in that the maximum field angle (B2) on the exit of the undersida ocular (24) is in the order of 30-60°.

24. A collimator for collimating light of narrow band frequency, **characterized in that** the collimating optic includes a waveguide plate (901, 601) into which light in the form of a collimated flat light beam (906) enters in a direction such that the light will be totally reflected multiply in the waveguide plate; in that one surface of the waveguide plate is provided with a phase grating (601D) having a successively increasing relief depth, so as to obtain essentially uniform light distribution out from the waveguide plate (901, 601) via the grating (601D).

25. A collimator according to Claim 24, **characterized in that** the collimating optic is comprised of two series-connected waveguide plates (901, 601).

26. A system according to any one of Claism 1-25, **characterized in that** the illumination optic includes a waveguide plate (901, 601).

27. A system according to any one of Claism 20-21, **characterized in that** the illumination optic on the entrance side of the picture-transmitting element (1) includes a plurality of waveguide plates (601R, 601G, 601B), where each waveguide plate collimates the light from a plurality of different-color light sources (2R, 2G, 2B).

28. A system according to Claim 27, **characterized in that** light of at most two colors per waveguide plate is collimated; and in that light from the different waveguide plates is combined by means of dichroic mirrors (5).

29. A system according to any one of Claims 3-28, **characterized in that** the colors are three in number; and in that the groups of pixel elements and the positive microlenses (94) have an L-shape.

30. A system according to Claim 29, **characterized in that** the pixel elements in similarly located corner regions of their respective picture element (315) have a respective transistor (93); in that the pixel elements in the L-shaped groups have their transistor (93) on a diagonal which extends through the centre pixel element of the group, which passes the corner contact point between the two remaining pixel elements of the pixel element group.

31. A system according to any one of Claims 3-28, **characterized in that** the colors are three in number; and in that the gorups of pixel elements are in row or column form.

32. A system according to any one of Claims 3-28, **characterized in that** the colors ar three in number; and in that the groups of pixel elements have a T-shape.

33. A system according to any one of Claims 3-28, **characterized in that** the colors are four in number; in that the groups of pixel elements are rectangular or square in shape; and in that these groups are diagonally arranged.

34. A system according to any one of Claism 1-33, **characterized in that** color filters are mounted on the pixel elements (PR, PG, Pb or PA, PB, PC, PD).

35. A system according to Claim 34, **characterized in that** the color filters are of the reflection type so that light of the wrong color is reflected.

36. A system according to any one of Claim 1-35, **charac-**

terized in that lasers, laser diodes, light emitting diodes or arrays (202) thereof are arranged as light sources for single-color light.

37. A system according to Claim 36, **characterized in that** the light from an array of single-color light sources (200) is combined with two DOE (201, 203).

38. A system according to Claim 37, **characterized in that** the various light sources are mutually phase locked.

39. A system according to Claim 37, **characterized in that** the various light sources have different wavelengths with a total band width of about 10 mm.

40. A system according to any one of Claims 1-36, **charac-terized in that** the primary light sources are comprised of a plurality of light emitting bodies (213) in lamps that include a rearwardly lying reflector (211) of an ellipsoidal, parabolic or spherical type.

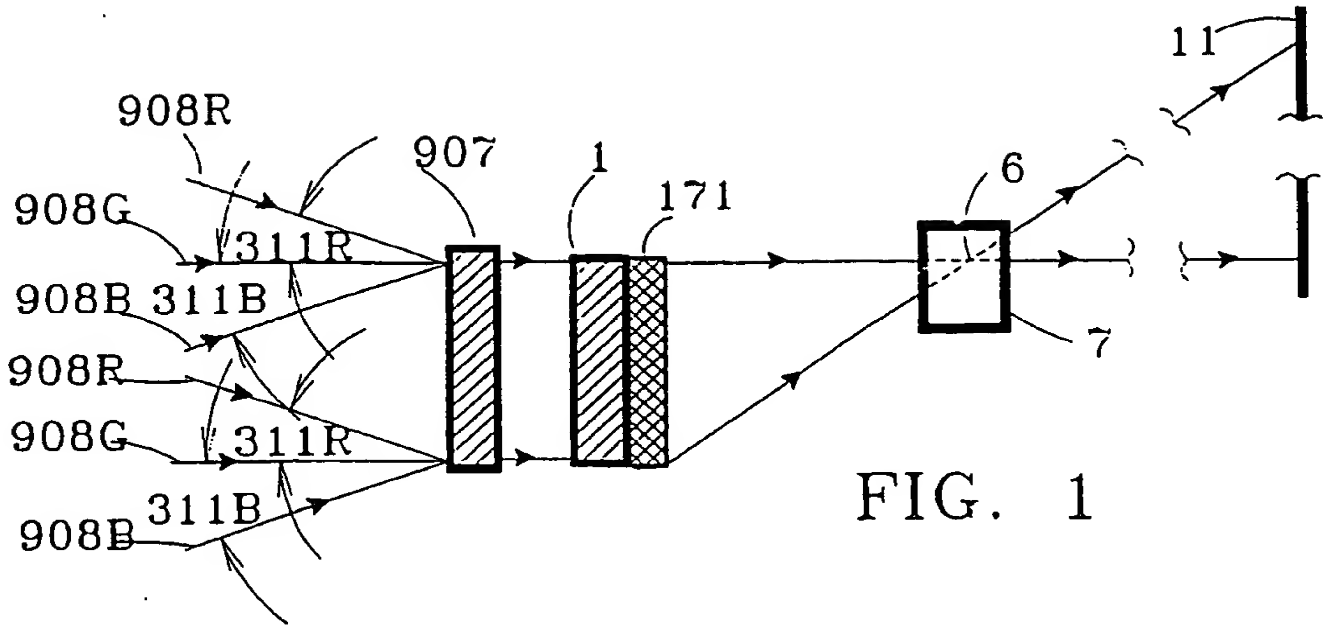


FIG. 1

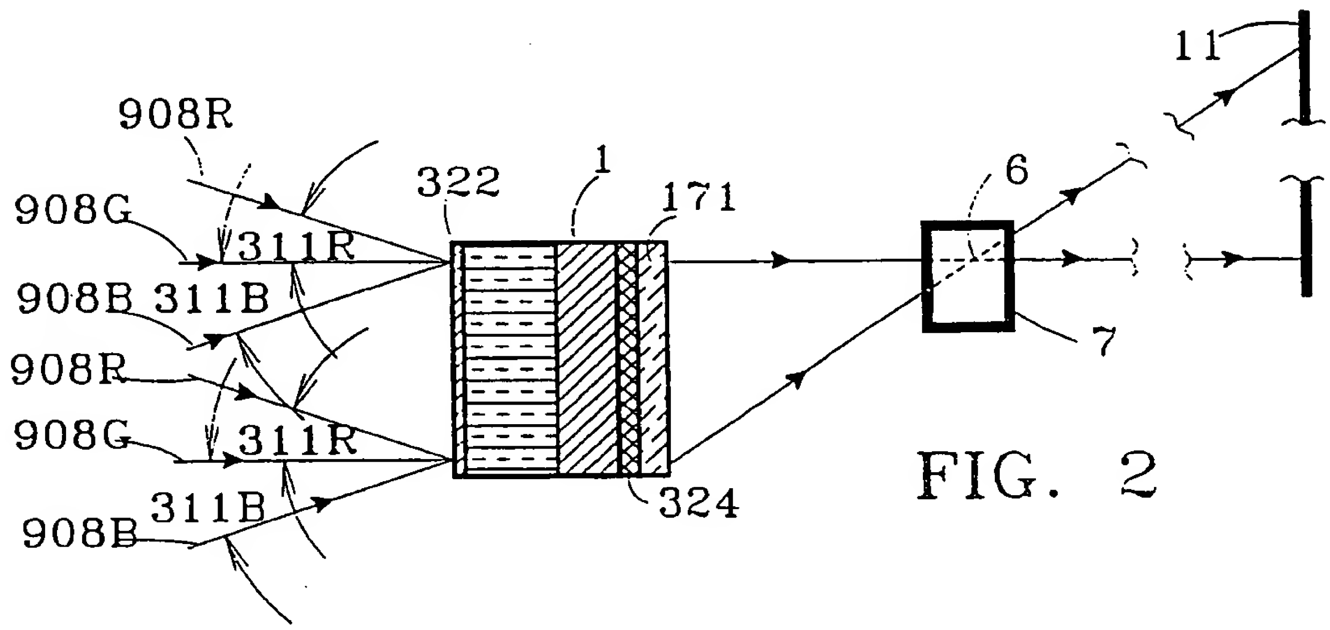


FIG. 2

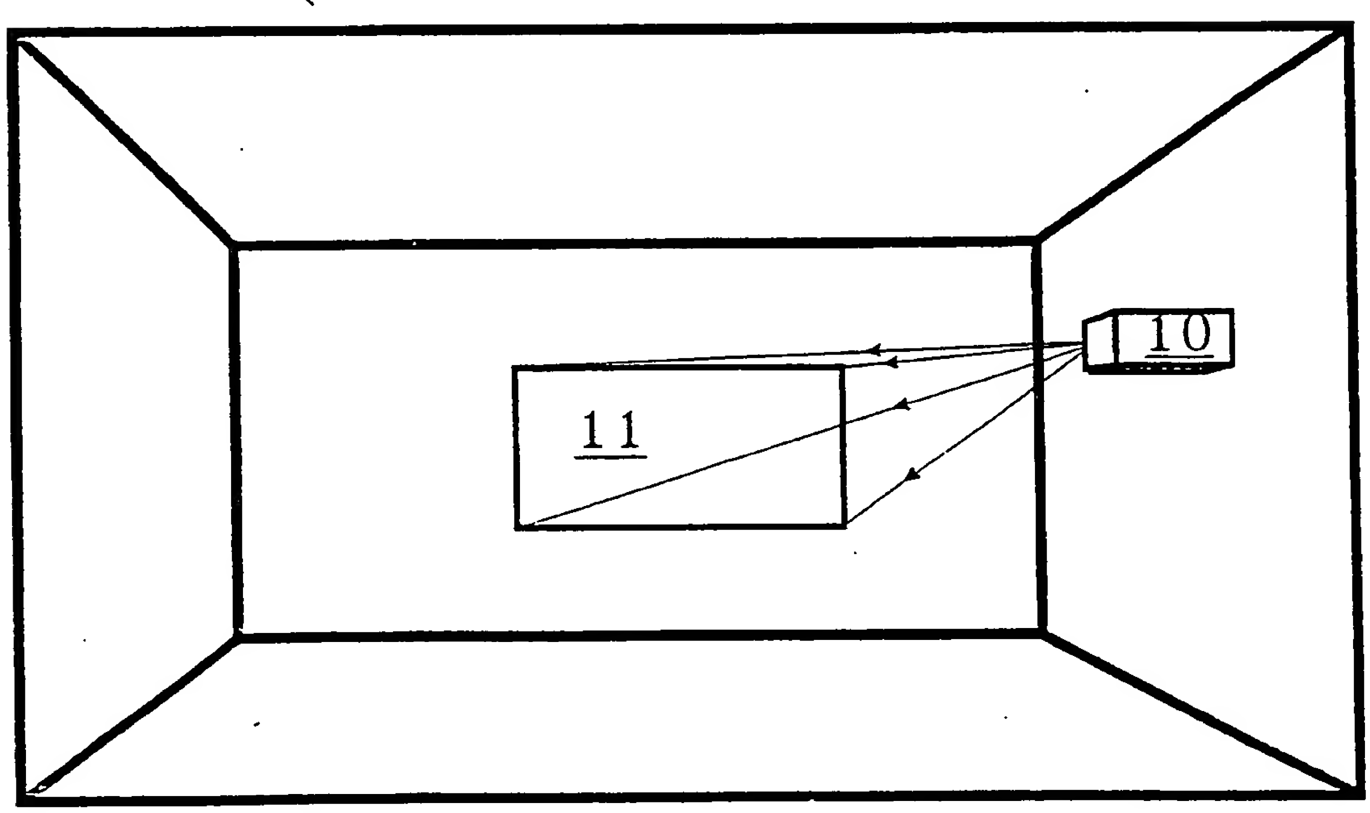


FIG. 3

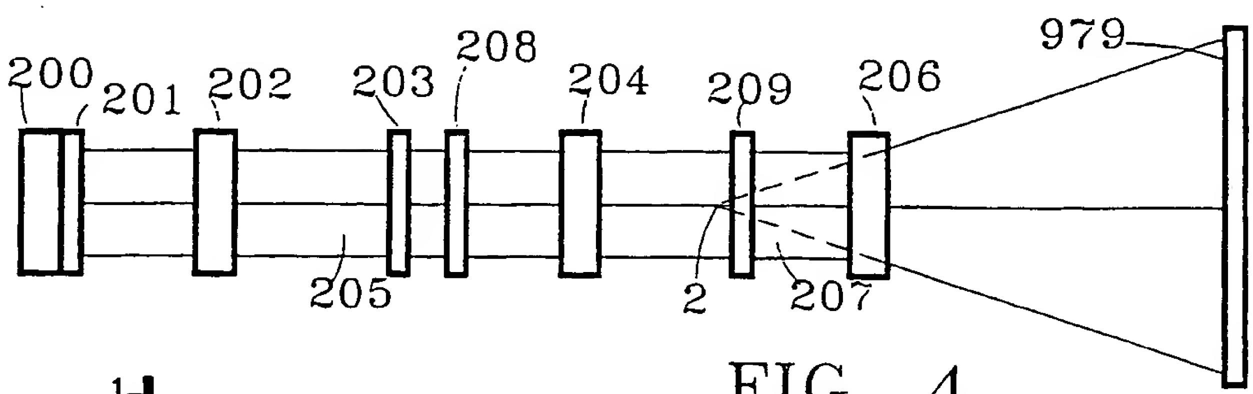


FIG. 4

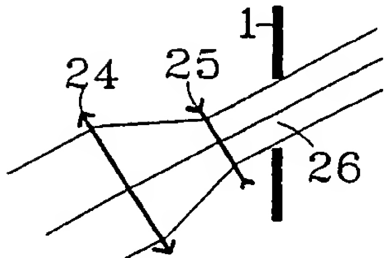


FIG. 5

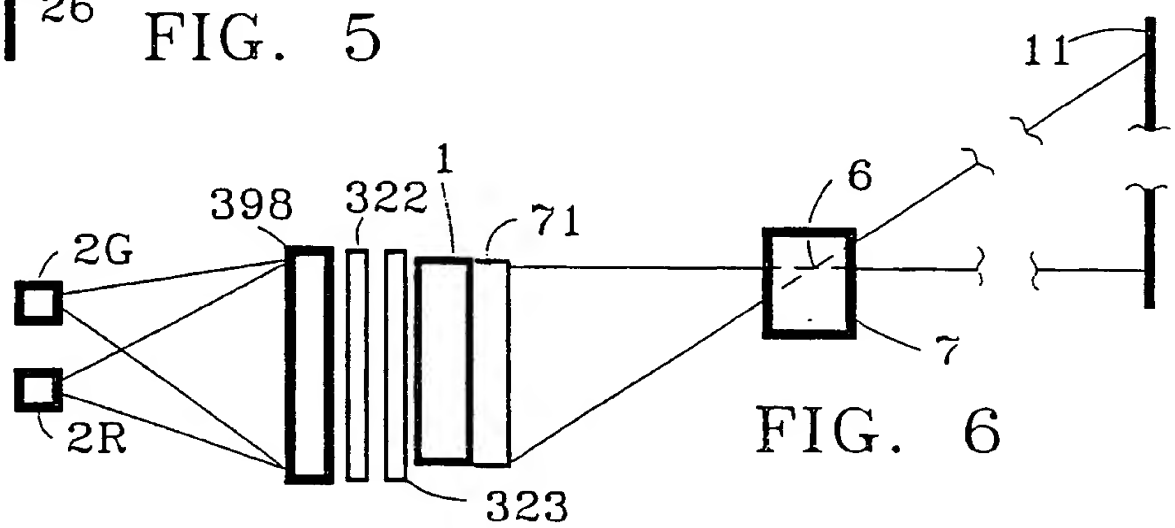


FIG. 6

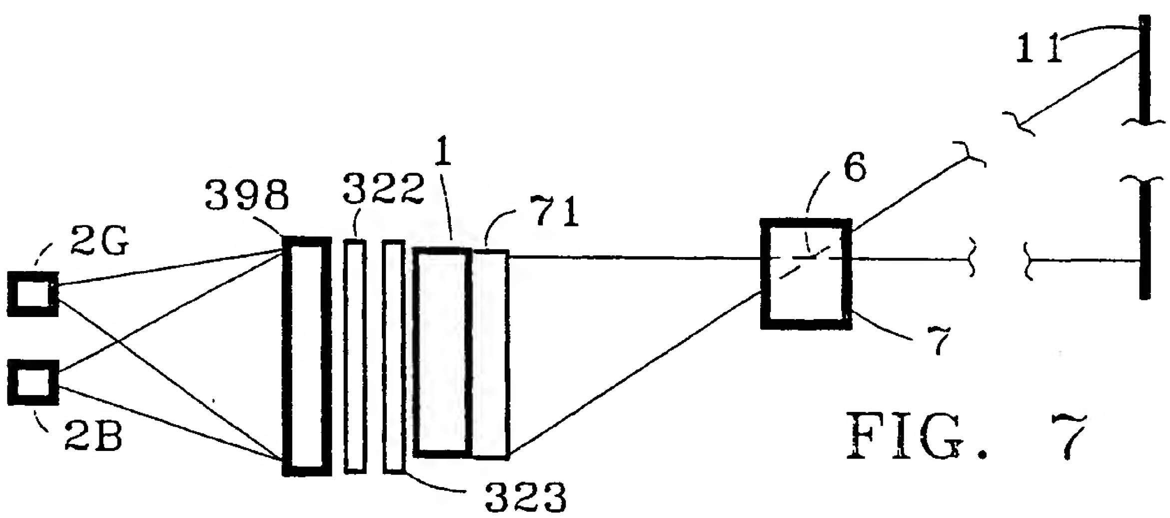


FIG. 7

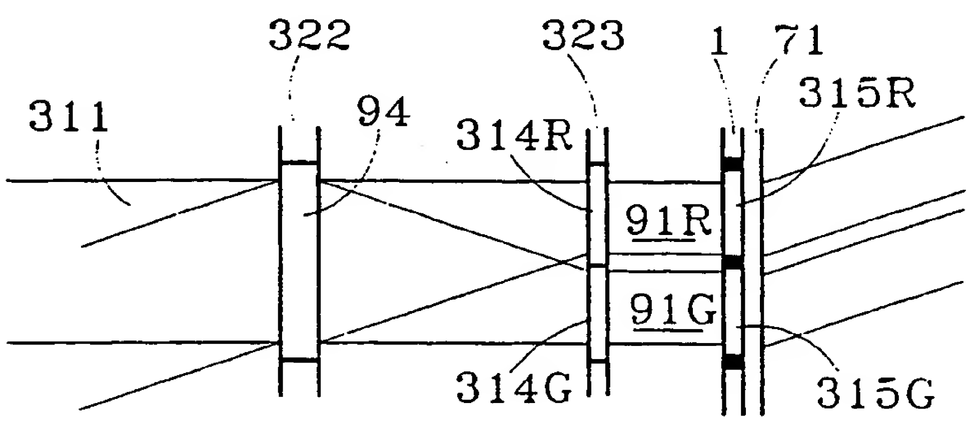


FIG. 8

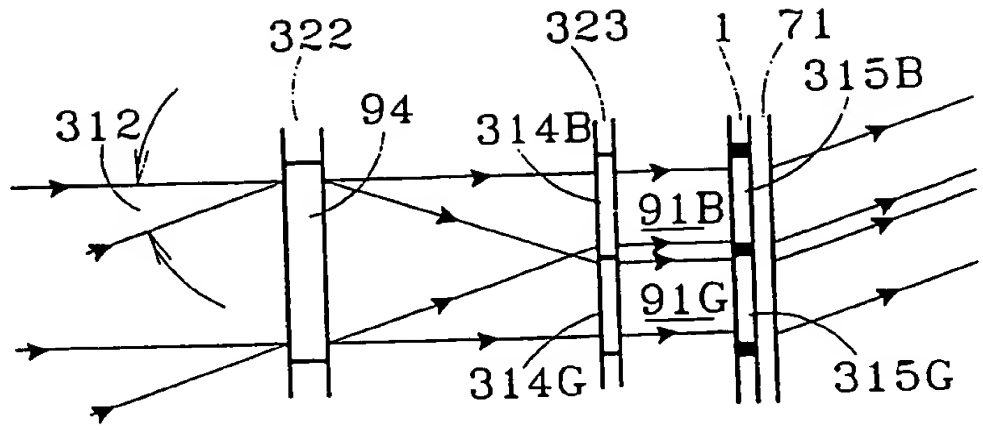


FIG. 9

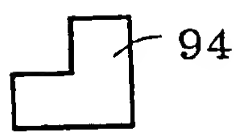


FIG. 10

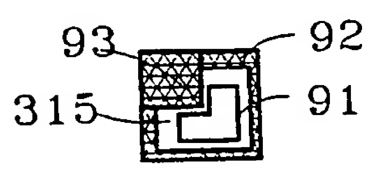


FIG. 11

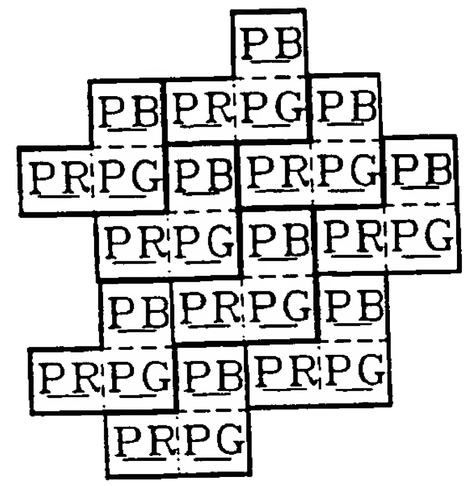


FIG. 12

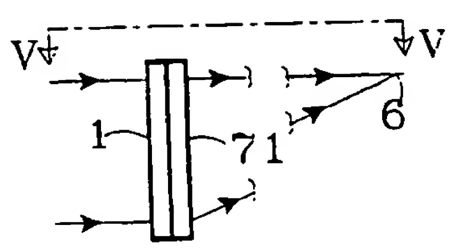


FIG. 13

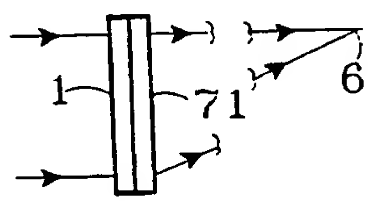


FIG. 14

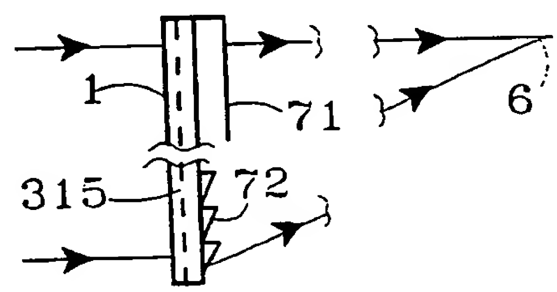


FIG. 15

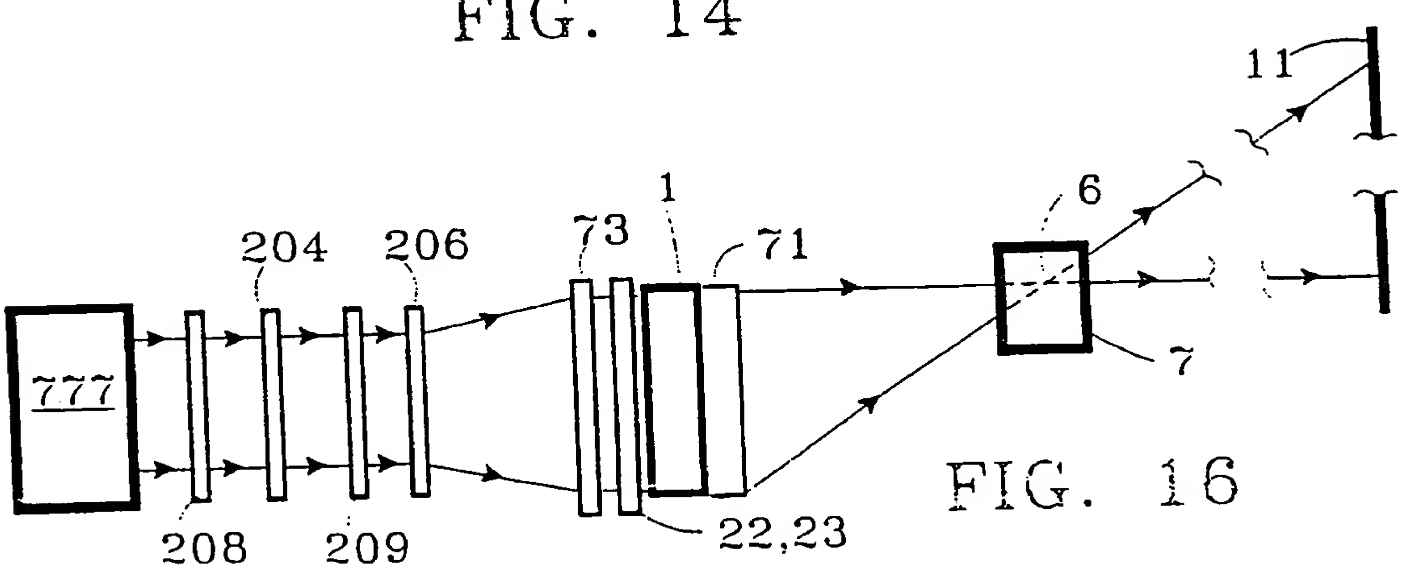


FIG. 16

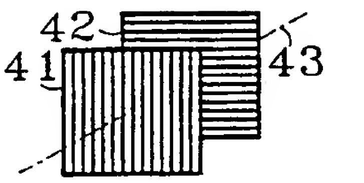


FIG. 17

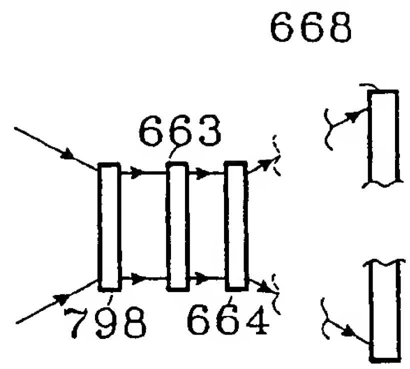


FIG. 18

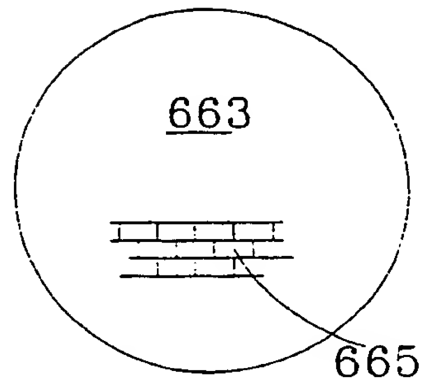


FIG. 19

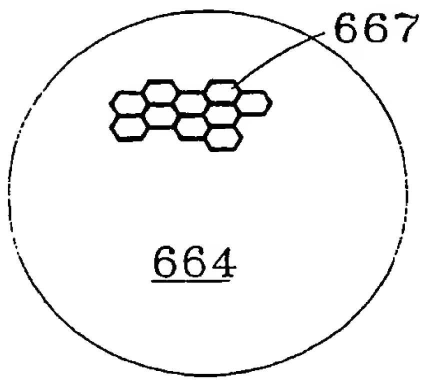


FIG. 20

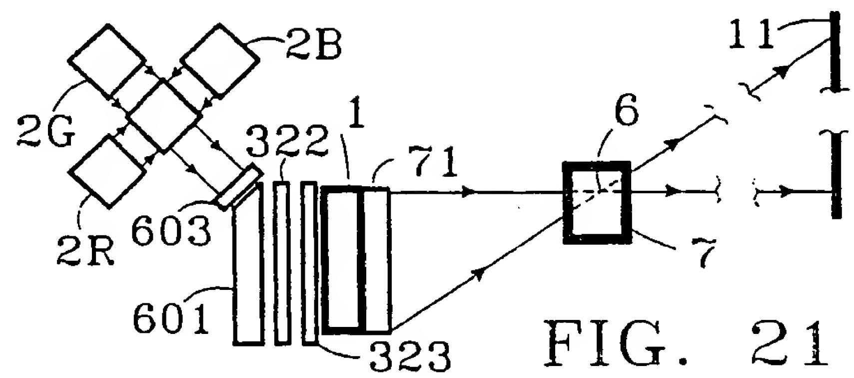


FIG. 21

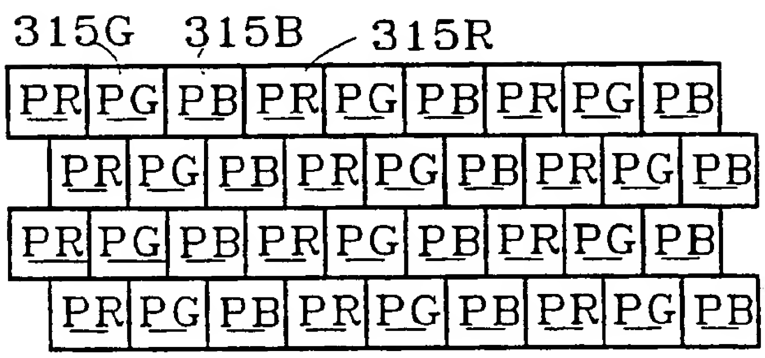


FIG. 22

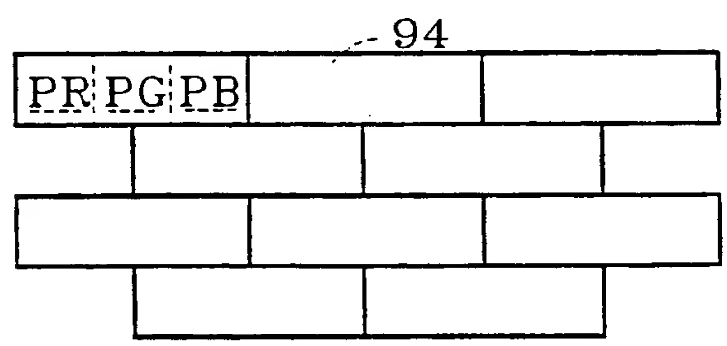


FIG. 23

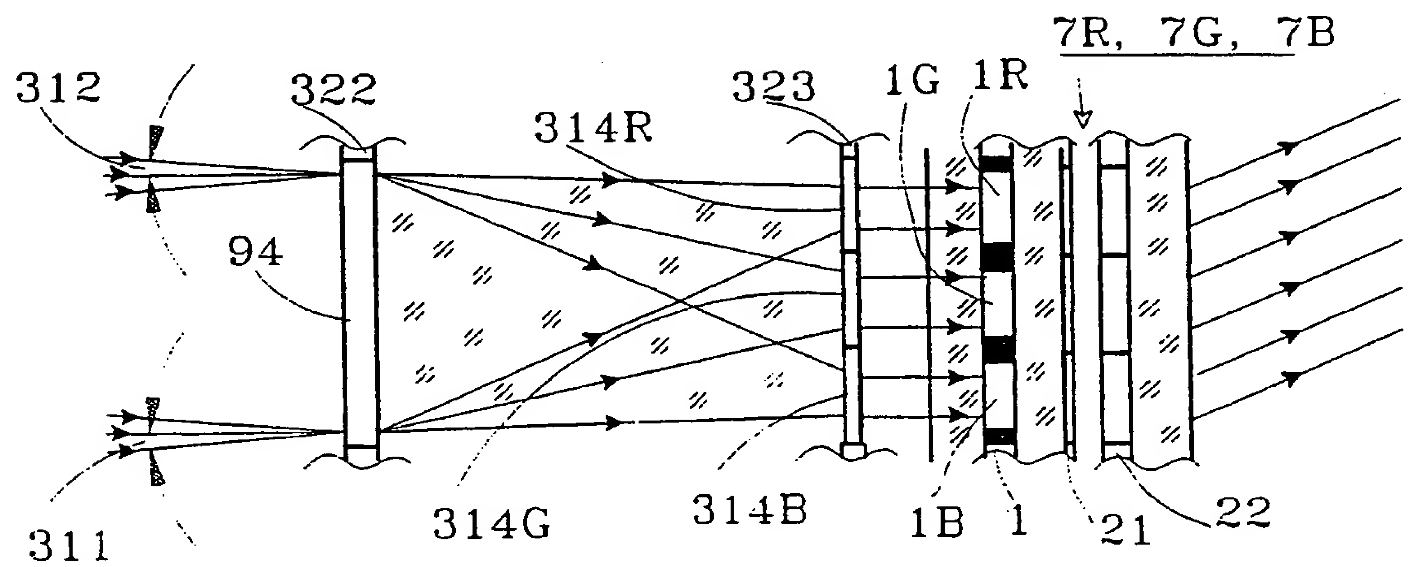


FIG. 24

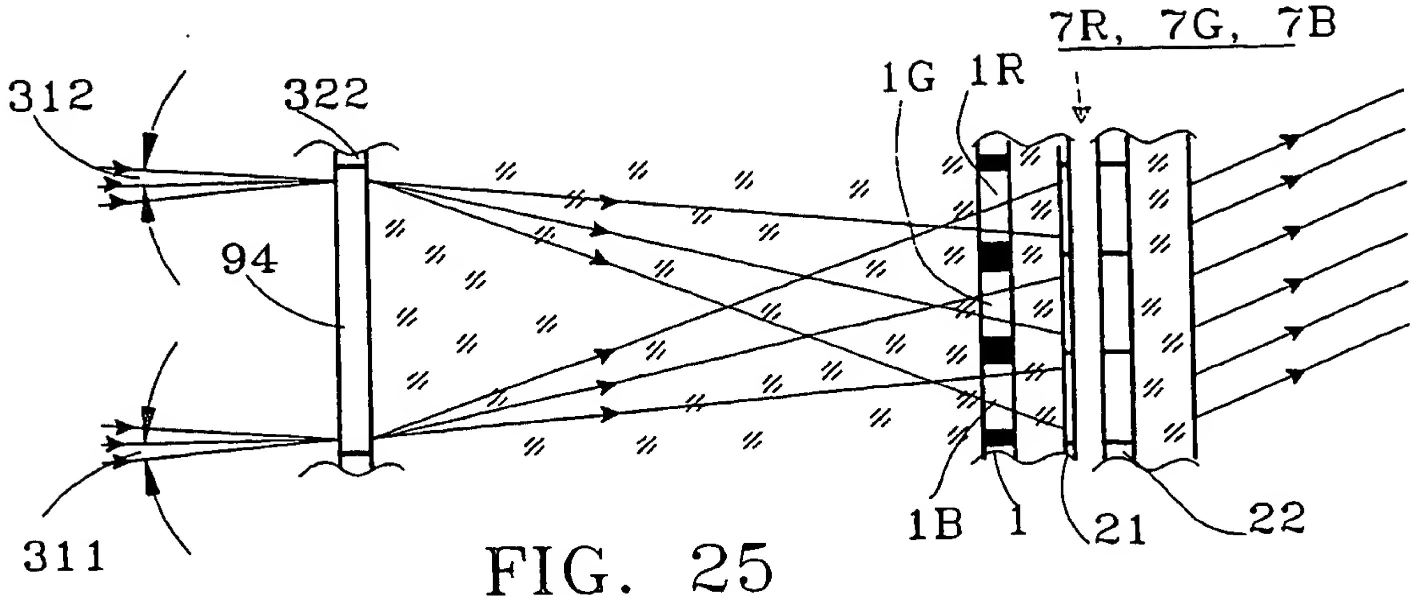


FIG. 25

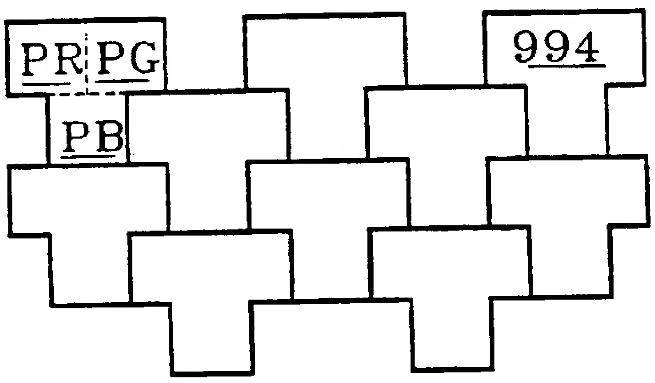


FIG. 26

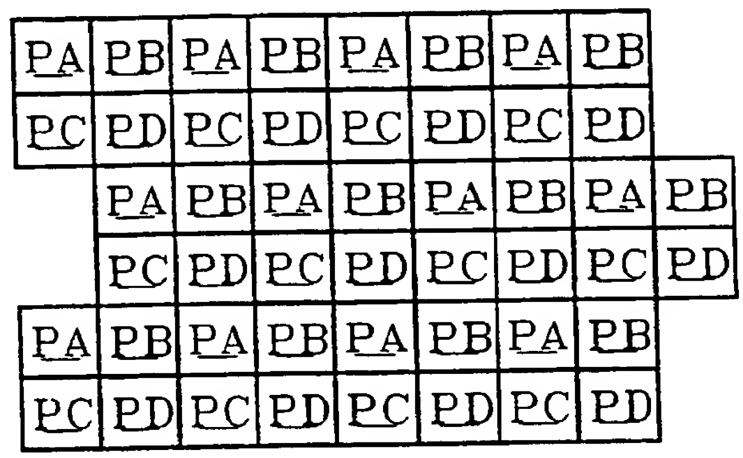


FIG. 27

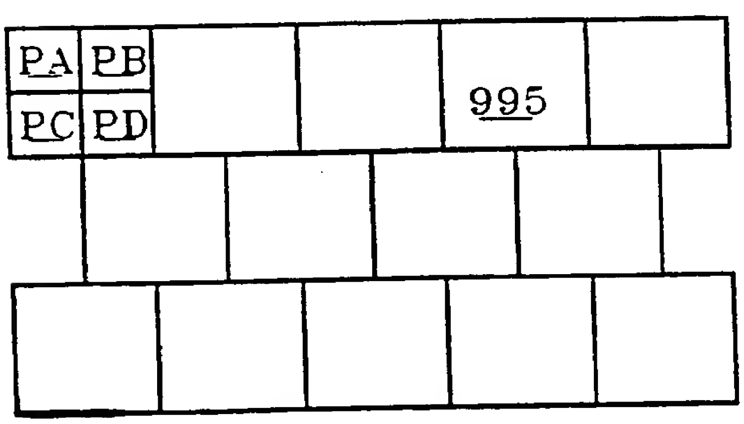


FIG. 28

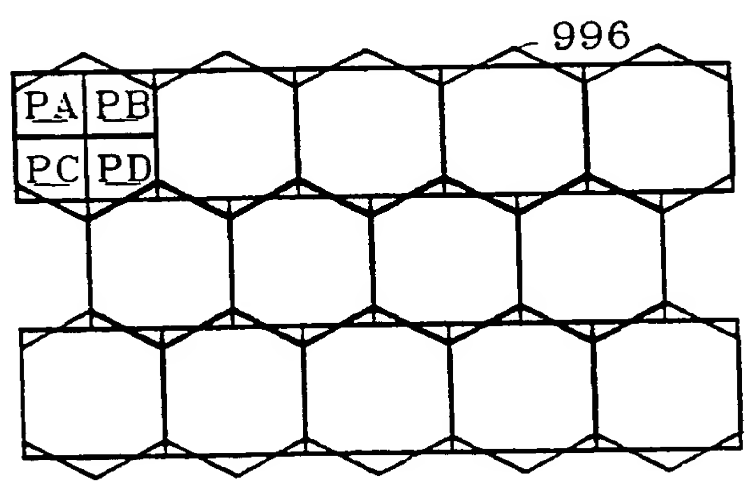


FIG. 29

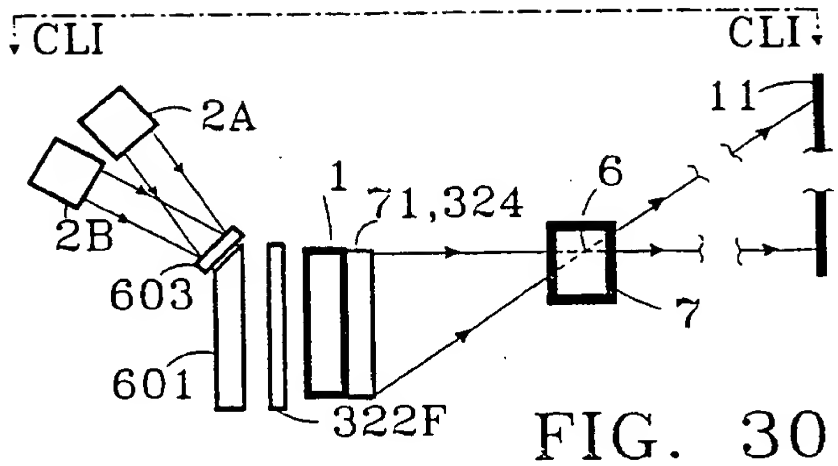


FIG. 30

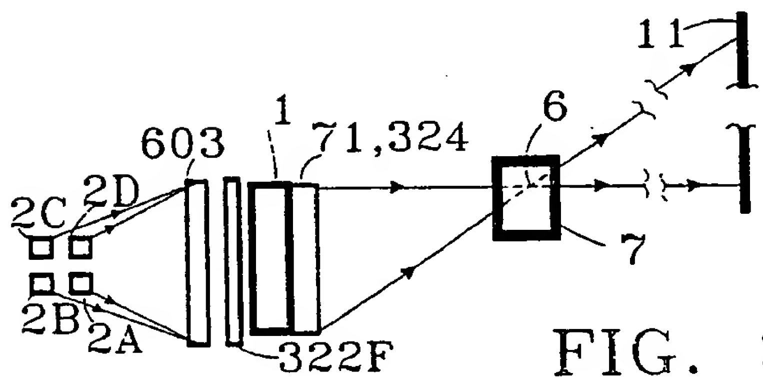


FIG. 31

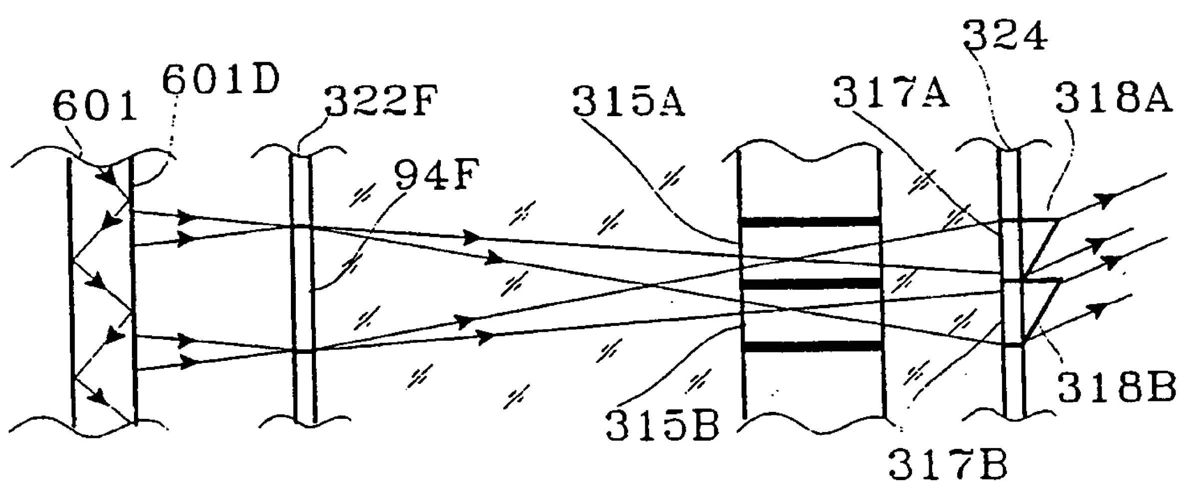


FIG. 32

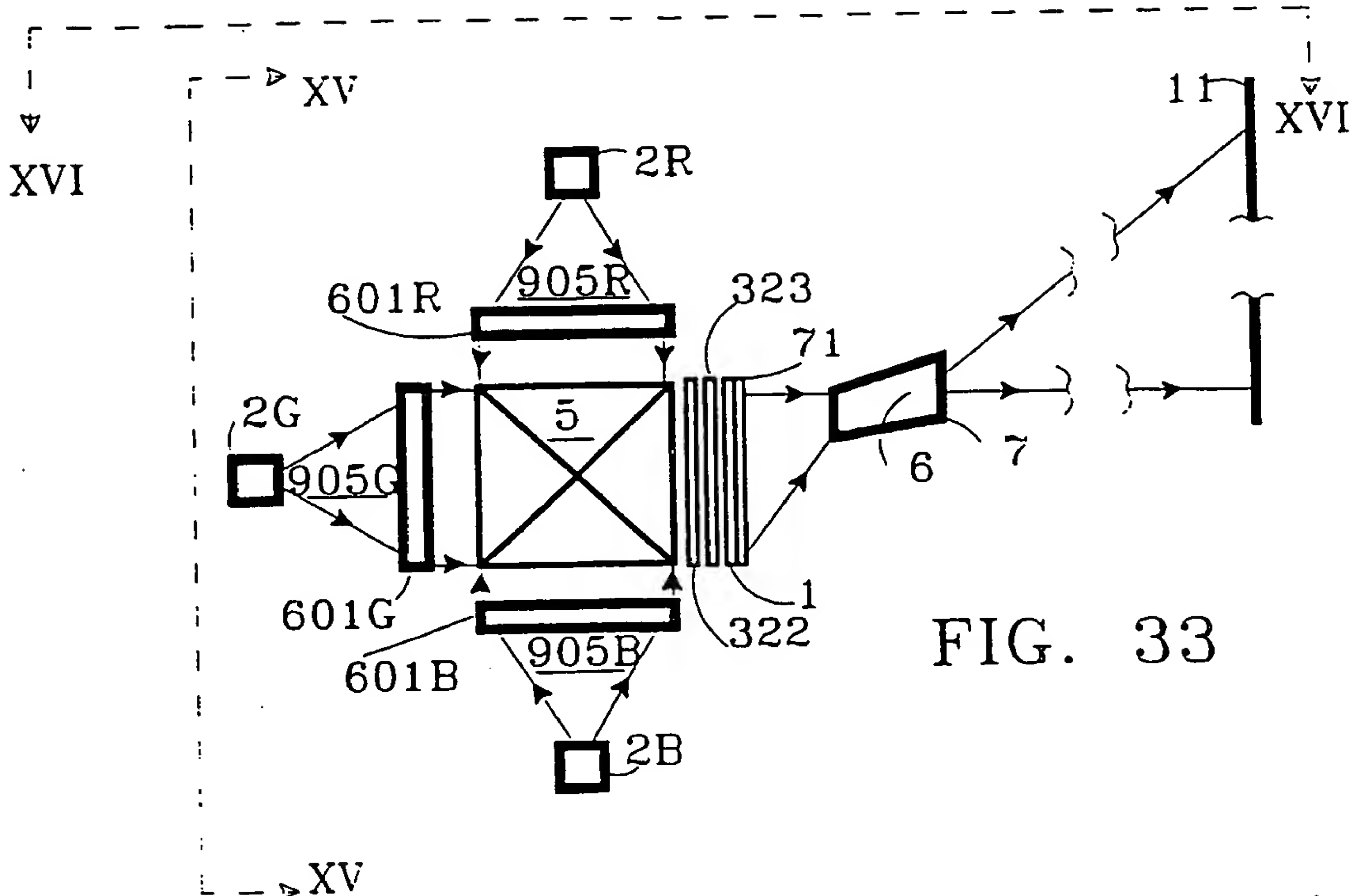


FIG. 33

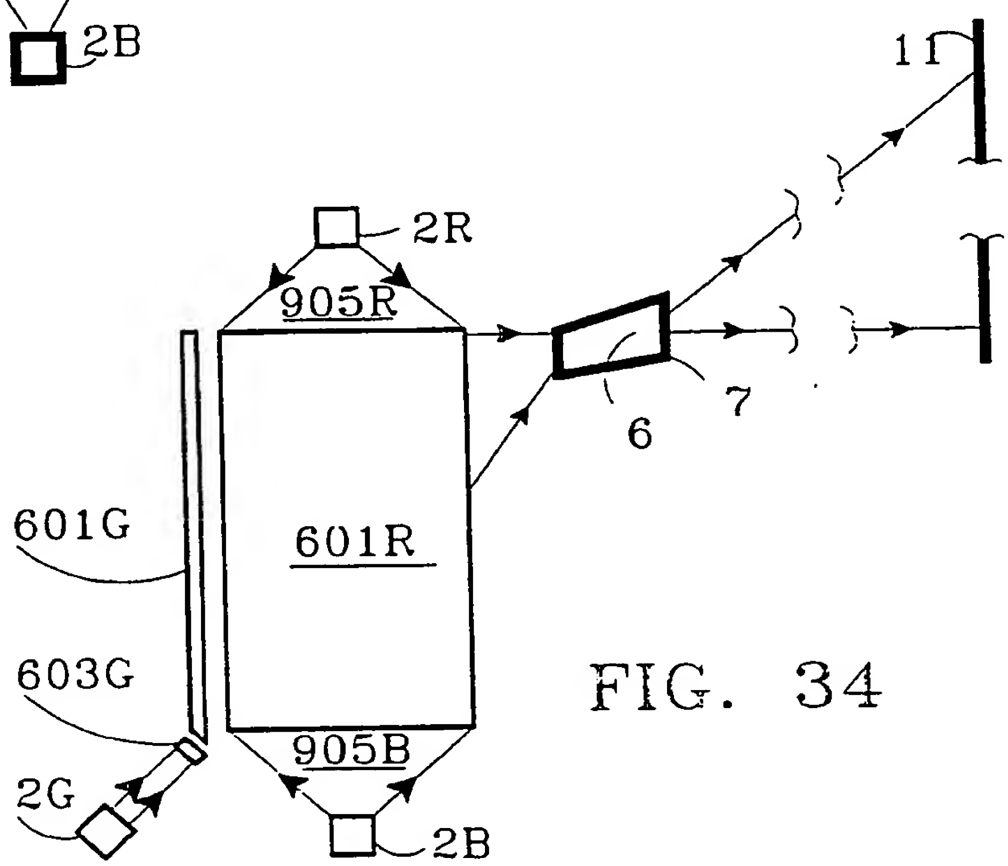


FIG. 34

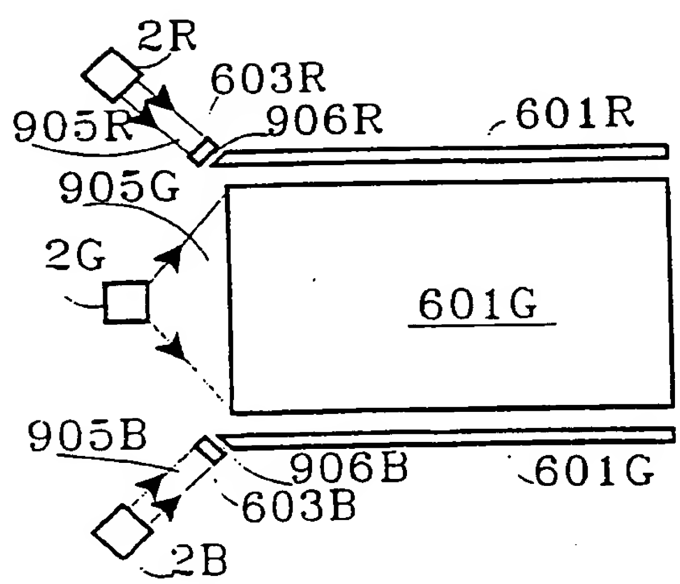
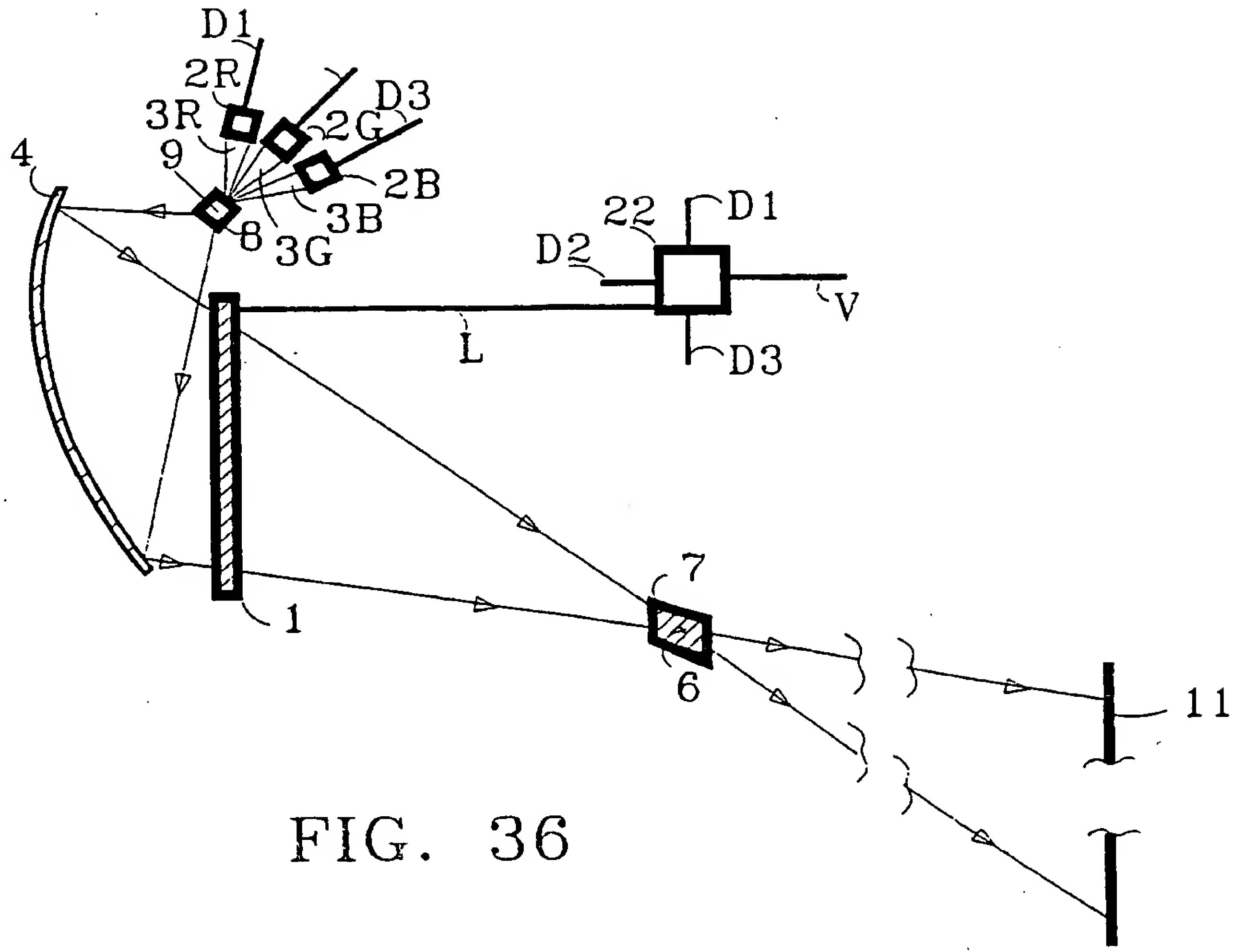


FIG. 35


D1
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D3
2G
9
2B
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3B
8
3G
22
D1
D2
V
L
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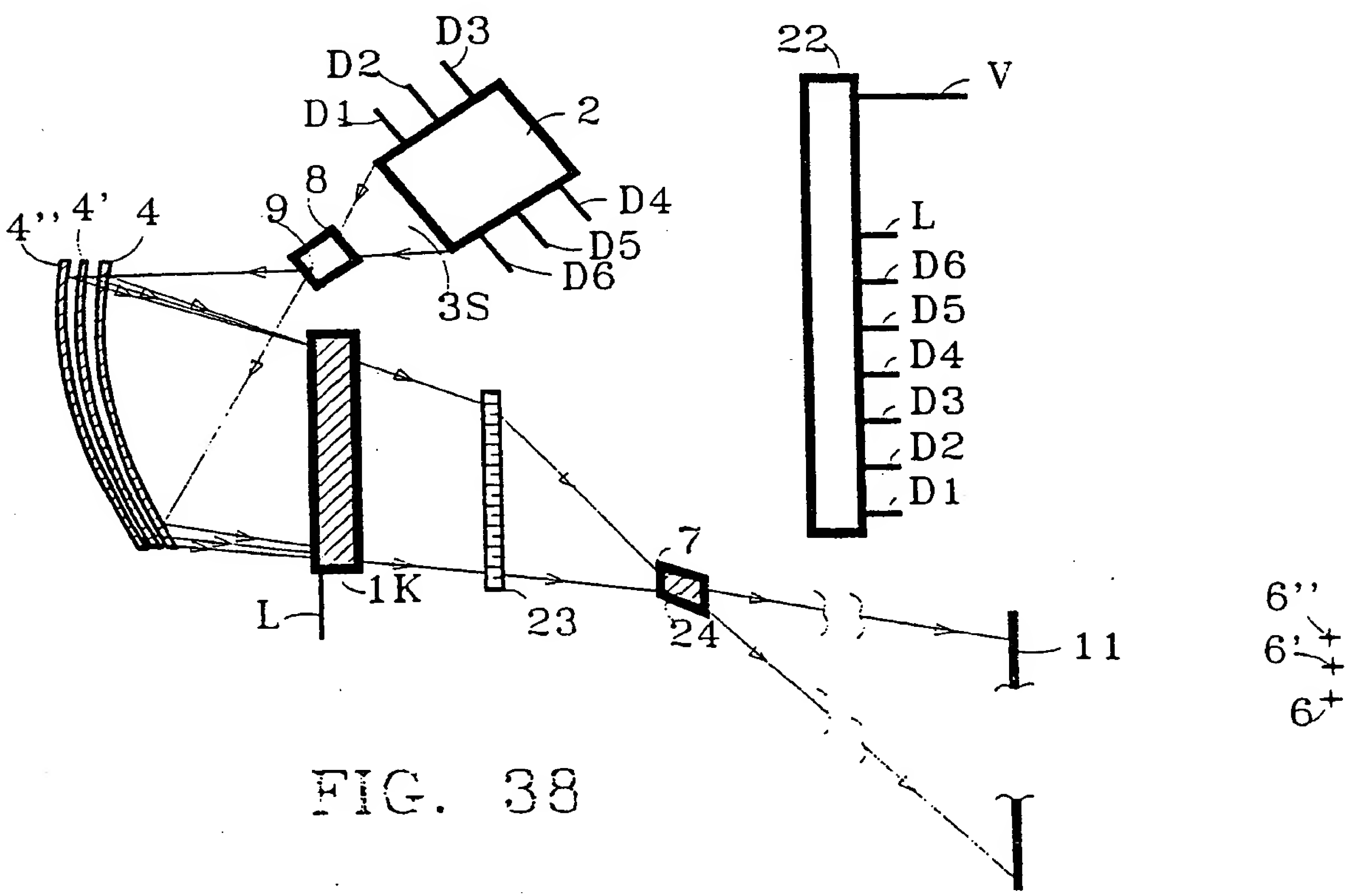
7
1
6
11

FIG. 36


D3
D2
22
V
D1
2
8
9
D4
4'' 4' 4
D5
D6
3S
L
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D4
D3
D2
D1
7
L
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23
24
11
6''
6'
6

FIG. 38

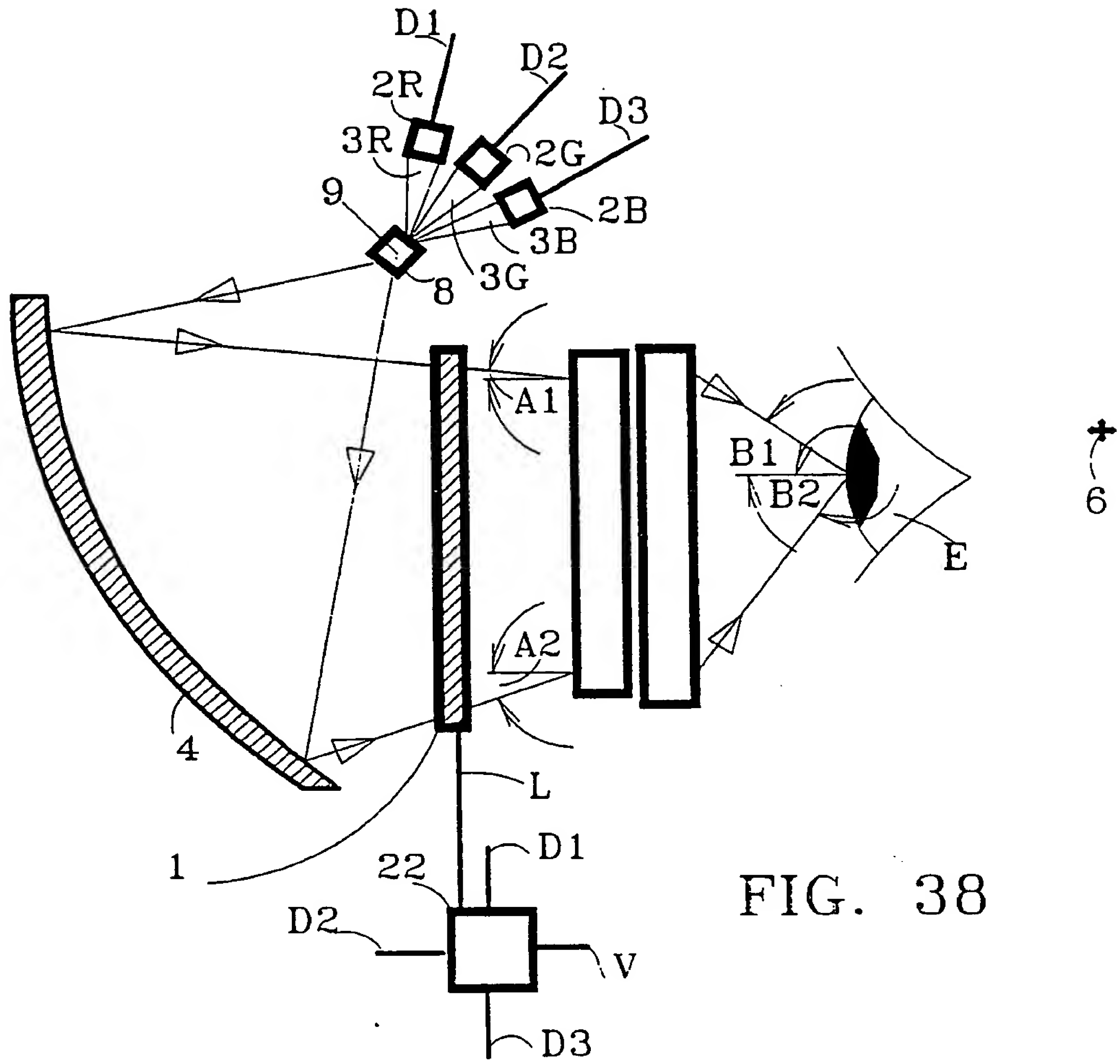

FIG. 38

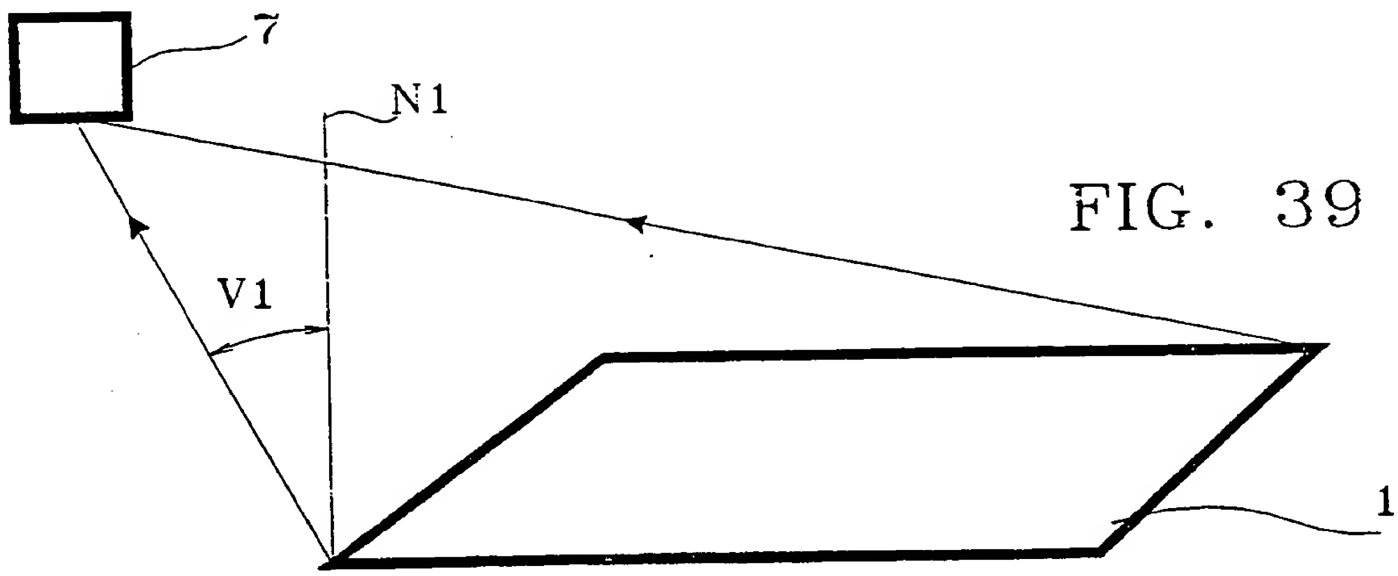

FIG. 39

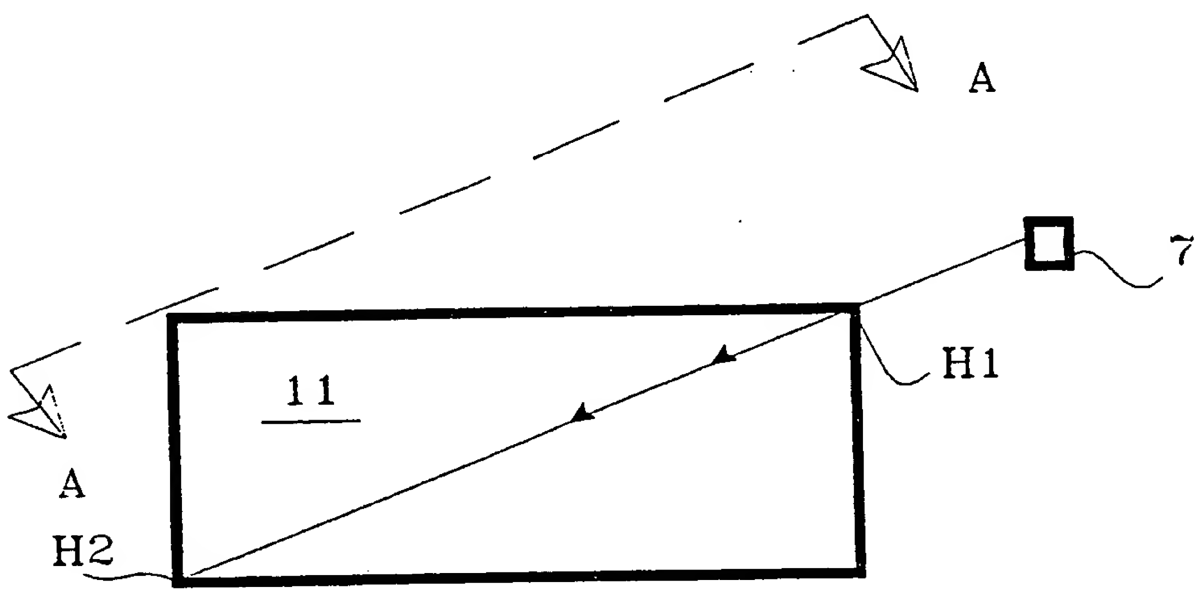

FIG. 40

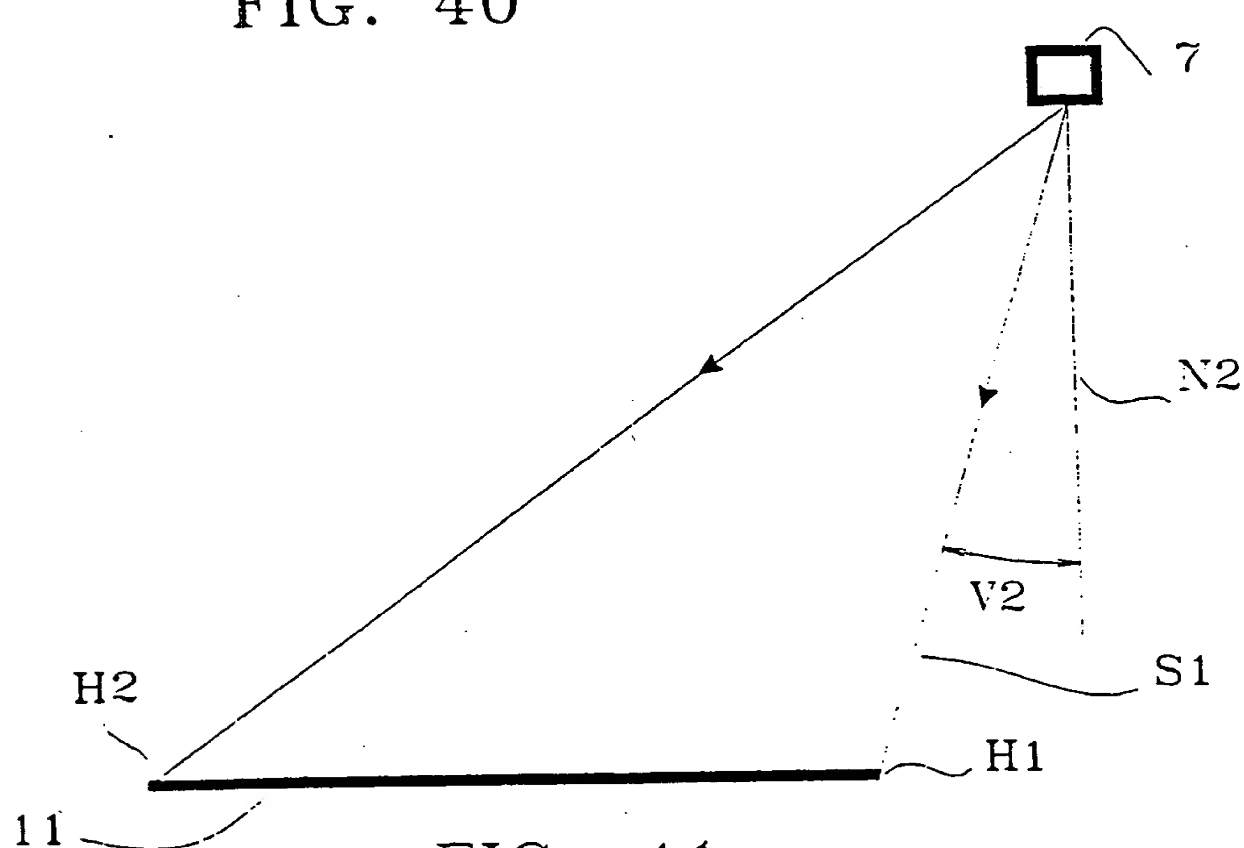

FIG. 41

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00251

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 : G03B 33/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 : G03B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CLAIMS, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 5108172 (FLASCK), 28 April 1992 (28.04.92) --	1-13,16-23, 26-40
A	US, A, 5022750 (FLASCK), 11 June 1991 (11.06.91) --	1-13,16-23, 26-40
A	US, A, 5161042 (HAMADA), 3 November 1992 (03.11.92) --	1-13,16-23, 26-40
A	US, A, 4995718 (JACHIMOWICZ ET AL), 26 February 1991 (26.02.91) -- --------	1-13,16-23, 26-40

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 June 1994	11 -07- 1994
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Björn Kallstenius Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00251

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 14,15 concerning a diffusor.

Claims 24,25 concerning a kollimator.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

28/05/94

International application No.
PCT/SE 94/00251

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 5108172	28/04/92	AU-A- 6147190	03/04/91
		EP-A- 0486523	27/05/92
US-A- 5022750	11/06/91	AU-A- 6147190	03/04/91
		EP-A- 0486523	27/05/92
US-A- 5161042	03/11/92	EP-A- 0465171	08/01/92
US-A- 4995718	26/02/91	CA-A- 2025954	16/05/91
		EP-A- 0428971	29/05/91